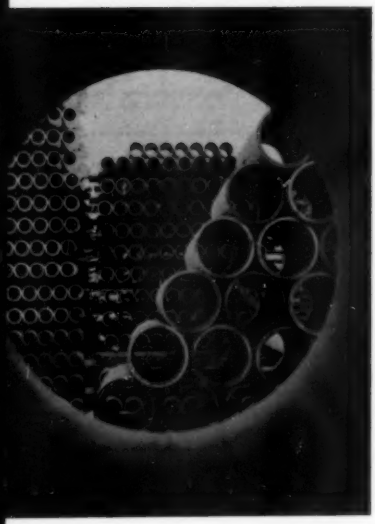
NOVEMBER 1959

# Journal

## AMERICAN WATER WORKS ASSOCIATION

VOL. 51 • NO. 11



*Pipe this—*
*It's mainly main*
*that's waiting for the train*
*(see P&R p. 48)*

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**LONG-RANGE WEATHER FORECASTING**
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**DISINFECTANTS AND HEXADECANOL EFFECTIVENESS**
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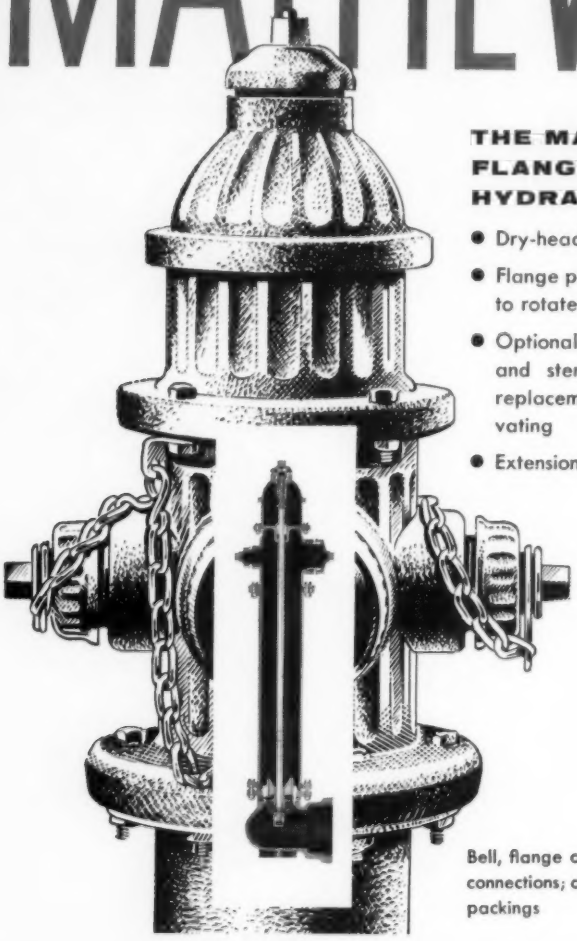
Baylis, Hudson, Kennedy, Aultman, Lindenbergh

# MATHEWS



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# Journal

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November 1959

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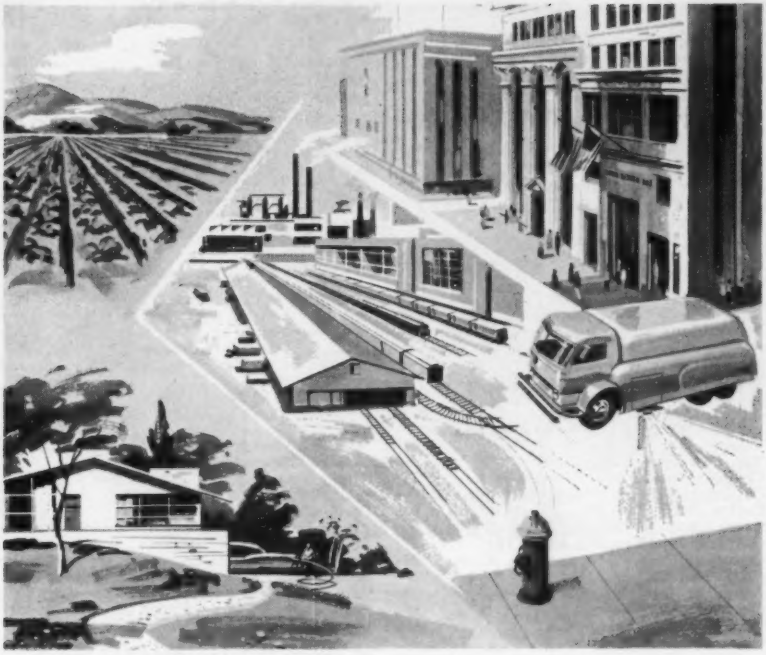

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# *Coming Meetings*

## AWWA SECTIONS

**Nov. 15–19**—Florida Section, at Hillsboro Hotel, Tampa. Secretary, J. G. Simmons, Plant Supt., West Palm Beach Water Dept., Box 1311, West Palm Beach.

**Nov. 19–21**—Cuban Section, Havana. Secretary, Juan Berasategui, Civ. Engr., Calle K, No. 303, Apdo. 22, Vedado, Havana.

**Spring 1960**

**Feb. 3–5**—Indiana Section, at Sheraton-Lincoln Hotel, Indianapolis. Secretary, C. H. Canham, State Board of Health, 1330 W. Michigan St., Indianapolis.

**Mar. 16–18**—Illinois Section, at Pick-Congress Hotel, Chicago. Secretary, D. W. Johnson, Research Engr., Cast Iron Pipe Research Assn., 3440 Prudential Plaza, Chicago 1.

**Mar. 17**—New England Section, at Statler Hotel, Boston, Mass. Secretary, R. M. Soule, Assoc. San. Engr., State Dept. of Public Health, 511 State House, Boston, Mass.

**Mar. 20–23**—Southeastern Section, at De Soto Hotel, Savannah, Ga. Secretary, N. M. de Jarnette, Engr., Water Quality Div., State Dept. of Public Health, 309 State Office Bldg., Atlanta, Ga.

**Mar. 23–24**—West Virginia Section, at Hotel Pritchard (tentative), Huntington. Secretary, H. W. Hetzer, Engr., Union Carbide Chemical Co., Box 8361, South Charleston.

**Apr. 5–7**—New York Section, at New York Sheraton-Binghamton, Binghamton. Secretary, Kimball Blanchard, New York Branch Sales Office, Neptune Meter Co., 2222 Jackson Ave., Long Island City.

**Apr. 20–22**—Nebraska Section, at Cornhusker Hotel, Lincoln. Secretary, J. J. Rossbach Jr., Civ. Engr., Metropolitan Utilities Dist., 3906 N. 48th St., Omaha.

*(Continued on page 8)*

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## Coming Meetings

(Continued from page 6)

**Apr. 20–22**—Kansas Section, at Broadview Hotel, Emporia. Secretary, H. W. Badley, Repr., Neptune Meter Co., 119 W. Cloud, Salina.

**Apr. 22**—California Section, at Mark Thomas Inn, Monterey. Secretary, R. E. Dodson Jr., Supt. of Water, Dept. of Utilities, Balboa Park, San Diego.

**Apr. 24–26**—Canadian Section, at Statler Hotel, Buffalo, N.Y. Secretary, A. E. Berry, 72 Grenville St., Toronto, Ont.

**Apr. 28–30**—Montana Section, at Northern Hotel, Billings. Secretary, A. W. Clarkson, Asst. Director, Div. of Environmental Sanitation, State Board of Health, Helena.

**May 4–6**—Pacific Northwest Section, at Benson Hotel, Portland, Ore. Secretary, F. D. Jones, W. 2108 Maxwell Ave., Spokane 11, Wash.

### OTHER ORGANIZATIONS

Nov. 29–Dec. 4—ASME Annual Meeting, Chalfonte–Haddon Hall Hotel, Atlantic City, N.J.

Nov. 30–Dec. 4—27th Exposition of Chemical Industries, Coliseum, New York, N.Y.

Nov. 30–Dec. 11—Course on "Chemical Analyses for Water Quality," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

Dec. 1–2—Pulp, Paper, and Paperboard Industrial Waste Conference, sponsored by National Council for Stream Improvement, Edgewater Beach Hotel, Chicago, Ill. Write: Russell L. Winget, Exec. Secy., National Council for Stream Improvement, Inc., 271 Madison Ave., New York 16, N.Y.

### 1960

Jan. 6–8—Conference on "Economics of Pollution Control," Hotel Netherland-Hilton, Cincinnati, Ohio, sponsored by Sanitary Engineering Div., ASCE.

Jan. 25–29—Course on "Recent Developments in Water Bacteriology," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

Jan. 27–28—2nd Sanitary Engineering Conference, University of Illinois, Urbana, Ill., cosponsored by the State Department of Public Health and the university's Department of Civil Engineering. Subject of the conference is "Radiological Health Aspects of Water Supply." Write: William J. Downer, Asst. Chief. San. Engr., Dept. of Public Health, Springfield, Ill.

Jan. 31–Feb. 5—AIEE, New York, N.Y.

Feb. 1–5—ASTM Committee Week, Sherman Hotel, Chicago, Ill.

Feb. 14–18—American Institute of Mining, Metallurgical & Petroleum Engineers, Hotel Statler, New York, N.Y.

Mar. 14–18—National Assn. of Corrosion Engineers Annual Convention, Memorial Auditorium, Dallas, Tex.

Apr. 3–8—6th Nuclear Congress, Coliseum, New York, N.Y., sponsored by EJC and other engineering and scientific societies, including AWWA.

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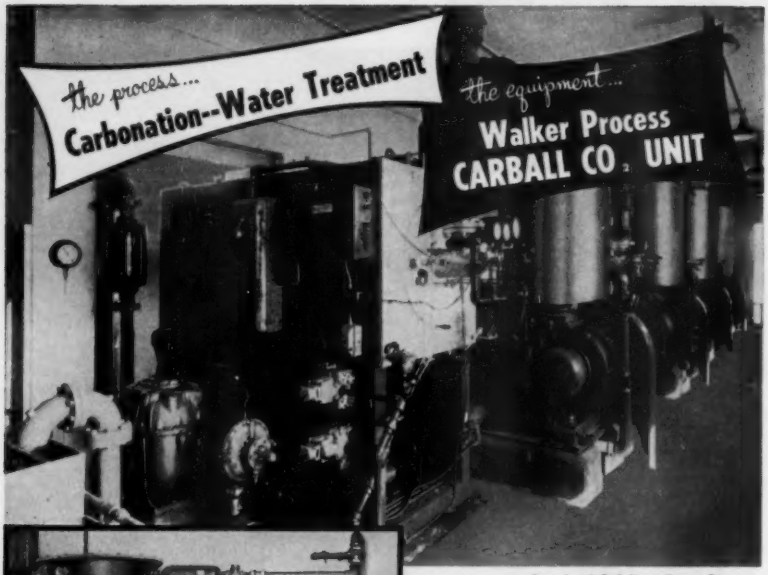
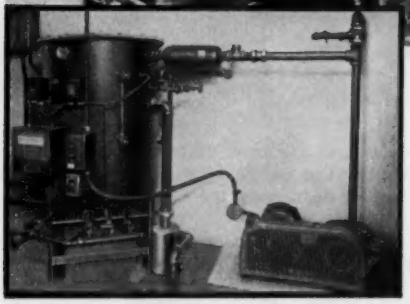


Four size 4 Carballs at Kansas City, Mo. burn either gas or oil to produce max. of 40,000 lbs. $CO_2$/day. Size "O" unit at left produces 570 lbs. $CO_2$/day for Jefferson, Iowa Water Plant.

# CARBALL
## $CO_2$ UNIT

Walker Process now offers carbonation units for all lime softening plants from the very small to the largest. Sizes range from the new "OO" unit with minimum capacity of 55 lbs. $CO_2$/day to the No. 4 at maximum output of 10,000 lbs. $CO_2$/day.

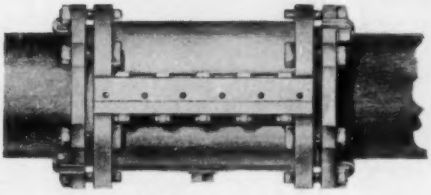
Engineers can readily provide an entire carbonation system by simply specifying the appropriate size CARBALL in combination with Walker Process SPARJER diffusers . . . . . assuring

**50% More $CO_2$** — **Unique Absorption Method**
**Clean, Tasteless Gas** — **Economical Operation**
**100% Combustion** — **Factory Tested Package System**

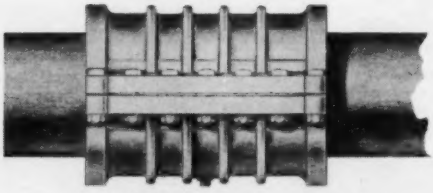
*Write for bulletins 7W83 - 7W85 and 7W88*

WALKER PROCESS

WALKER PROCESS EQUIPMENT INC.
FACTORY • ENGINEERING OFFICES • LABORATORIES
AURORA, ILLINOIS



Mechanical Joint Repair Sleeve



Bell (Hub) End Repair Sleeve

# INSTALL A SMITH SLEEVE

Smith Repair Sleeves are the answer to permanently repairing and quickly returning broken and cracked piping to service. Two types of Smith Repair Sleeves are available for installation on standard classes of cast iron pipe. Smith Mechanical Joint Repair Sleeves are produced in sizes 4″ thru 12″; Smith Bell (Hub) End in sizes 4″ thru 48″. Unskilled labor can speedily install Smith Mechanical Joint Repair Sleeves even in wet excavations. Bell End Repair Sleeves are most frequently installed with caulked lead joints. Smith Repair Sleeves reenforce the broken — cracked pipe and their service life equals the life of the pipe.

63

FIRE HYDRANTS · VALVES · SINCE 1896

**THE A.P. SMITH MFG. CO.**

EAST ORANGE, NEW JERSEY

# "I PREFER CAST IRON PIPE TO ANY

Recently a questionnaire was mailed to water utility managers all over the U. S. One question asked was: *What kind of pipe do you prefer and why?* With 42 states heard from, the vote is overwhelmingly in favor of cast iron! Here are typical comments from the survey:

"Strength, resistance to corrosion . . . economical first cost, low maintenance and operating cost, good flow characteristics."

—North Carolina

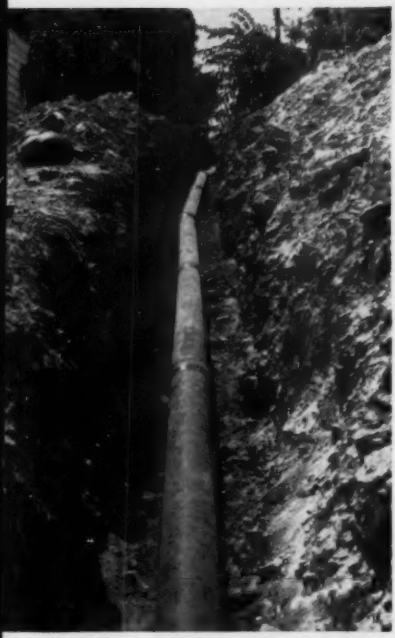
"Our main system is entirely cast iron. It holds up good in 'hot' soil conditions and will not rust out. We are nearing the century mark on some of it, and it gives no trouble."

—Kansas

"Long life—strength—ease of tapping. We are located, as a city, over old mine workings, and subsidence of earth causes trouble on other pipe to a greater extent than on cast iron."

—Illinois

## OTHER KIND"



"We have a very hilly city, pressures up to 170 p.s.i. Some of our mains are 90 years old. They were cast iron and are still giving good service."

—Iowa

"Having been used over a long period of time, it has proved its worth. Structurally safe. Easy to repair."

—California

**So many good reasons...**

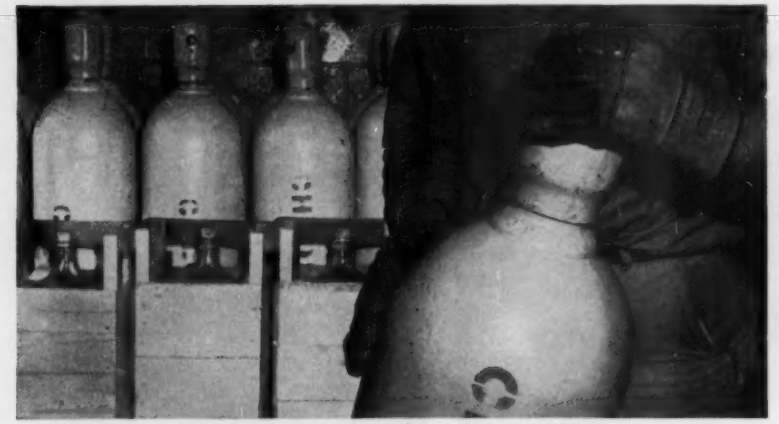
- LONG LIFE. The cast iron pipe you install today will perform economically 100 years from now.
- HIGH CAPACITY. Cement-lined cast iron pipe will deliver the full-rated flow all through the years. No other pipe, size for size, can carry more water.
- CORROSION RESISTANCE. Long life proves it. Most water utilities are still using the first cast iron pipe they installed.
- GREAT BEAM STRENGTH. Cast iron pipe resists the effect of heavy traffic, shifting soils.
- TREMENDOUS LOAD RESISTANCE. 6" cast iron pipe (Class 150) withstands a load of nearly 9 tons per foot!
- PRESSURE-TIGHT JOINTS. You have a complete choice of leak-proof, easy-to-assemble joints. You need a minimum of tools and crew.
- EASE OF TAPPING. No tapping saddles needed. Takes threading best of all kinds of pipe.

*... good reasons for* you *to choose*

**CAST IRON PIPE**

THE MARK OF THE 100-YEAR PIPE

Cast Iron Pipe Research Association,
Thos. F. Wolfe, Managing Director,
3440 Prudential Plaza, Chicago 1, Ill.



AT ELEVEN PLANTS ACROSS THE COUNTRY, Jones receives tank cars of Chlorine, repackages it in cylinders and 1-ton tanks, makes quick deliveries to users in area.

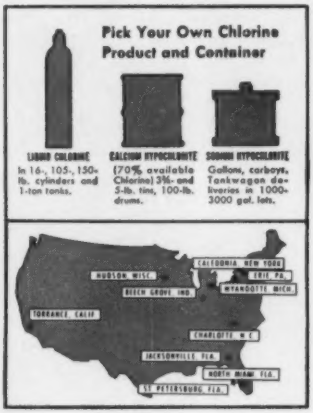
# ONE convenient source for all your chlorine needs

Get chlorine products any way you want them, in any amount you need, from just *one* dependable source—Jones Chemicals.

It eliminates hop-scotch buying of liquid chlorine, calcium hypochlorite, or sodium hypochlorite, and enables you to plan your needs and deliveries . . . avoid excess storage. Eleven Jones plants, strategically located across the U.S., stand ready to deliver chlorine products *when you need them.*

Get chlorine in any amount—from 16-lb. cylinders to 1-ton tanks. Jones packages high-purity chlorine in less than carload lots—then lets you pick the size and type of container you need.

Our trained technical staff will be glad to help you with your chlorine problems. Write for information and prices, or contact the Jones plant nearest you.

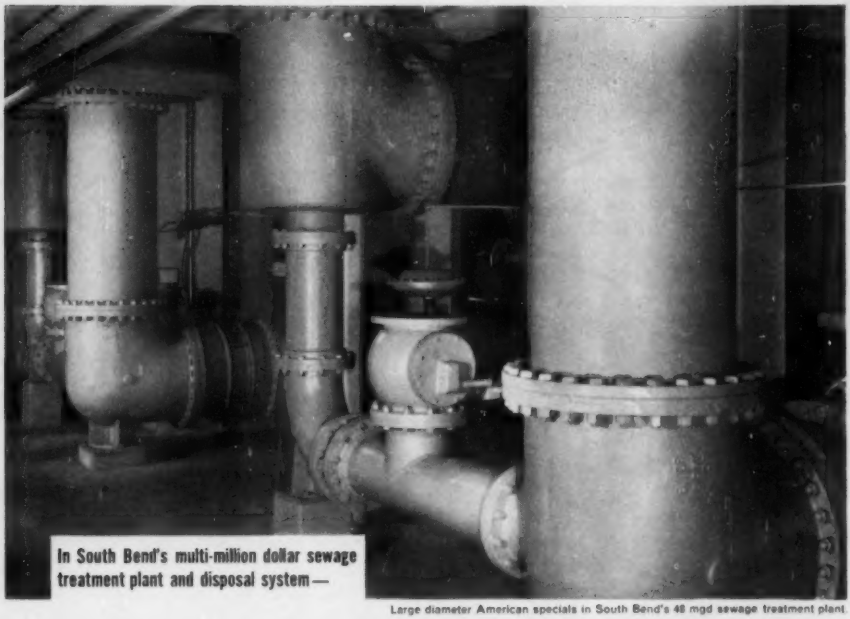



**John Wiley**

## JONES CHEMICALS, INC.

*"A good name in chemicals"*

Beech Grove, Ind. Charlotte, N. C. Jacksonville, Fla. St. Petersburg, Fla.
Caledonia, N. Y. Erie, Pa. North Miami, Fla. Torrance, Calif.
Hudson, Wis. Wyandotte, Mich. Warwick, N. Y.




Large diameter American specials in South Bend's 48 mgd sewage treatment plant.

# American Cast Iron Pipe and Fittings help solve a river pollution problem

A million pounds of American Cast Iron pipe and fittings were specified for South Bend, Indiana's, modern sewage treatment plant. Part of a long range sewage disposal improvement program, its completion has helped overcome a serious river pollution problem.

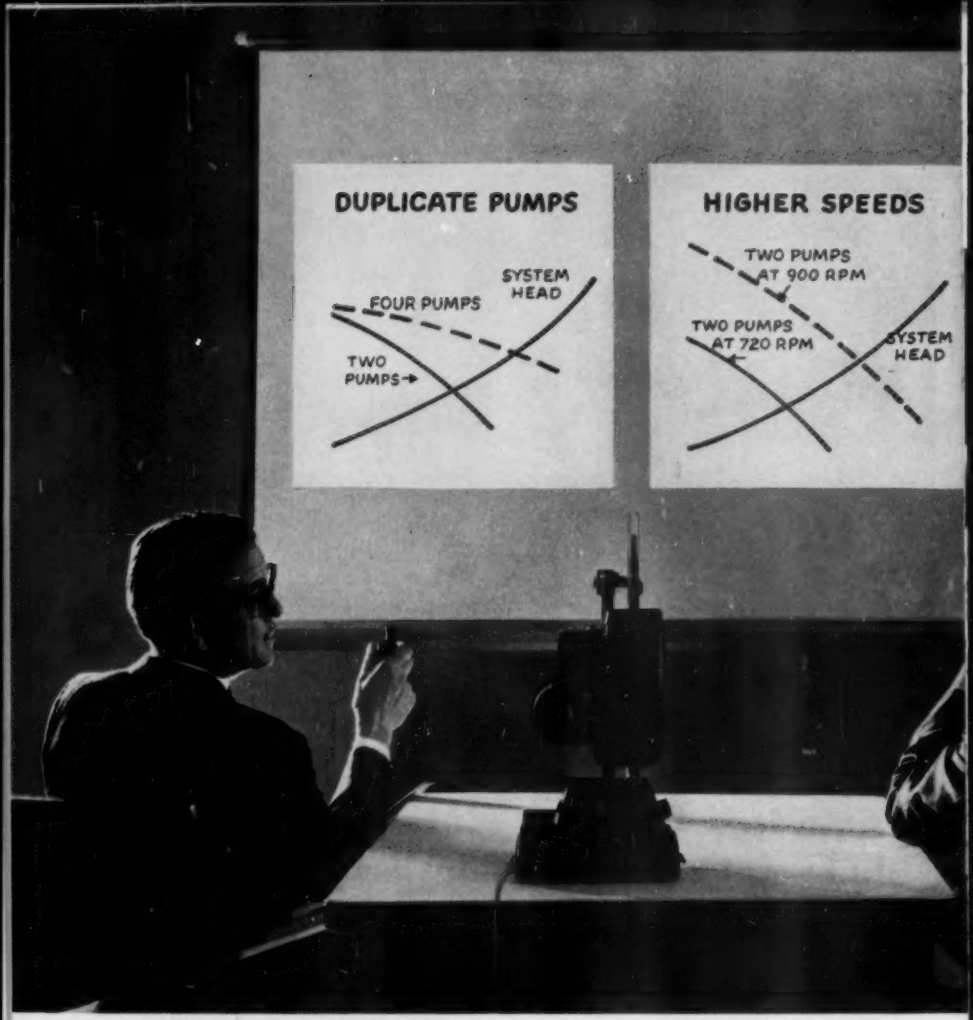
American Cast Iron pipe and fittings help overcome problems in many other areas as well. Where the need for long trouble-free service life must be met with economy, the proven strength, long life, corrosion resistance, and high flow capacity of American Cast Iron pipe provide the right answer.

In your new plant or system, as in South Bend and thousands of other sewage, water treatment, and industrial installations, American Cast Iron pipe, fittings and specials help solve today's most common problem—long range operational economy.

Call your nearby American Cast Iron Pipe Company representative for helpful facts while your new plant or addition is in the planning stage.

AMERICAN CAST IRON PIPE CO.
BIRMINGHAM ALABAMA

SALES OFFICES
New York City • Dallas
Chicago • Kansas City
San Francisco • Denver
Pittsburgh • Orlando
Minneapolis • Cleveland
Birmingham




Two ways of taking care of future demands for increased capacity are shown here. The chart on the left indicates the performance of 4 pumps operating in parallel. The chart on the right indicates the same conditions obtained with the use of 2 pumps operating at higher speeds.

# DUPLICATE PUMPS OR HIGHER SPEEDS?

**A discussion of the economics of multi-speed pumps for water works**

## WATER WORKS REPORT
from Worthington

Today, most engineers plan for expansion by providing space for duplicate pumps, or pumps that will operate in parallel giving increased capacity as water demand increases.

Another way of taking care of increased capacity is through the use of higher speeds. By providing for multi-speed operation in the future, it may be possible to save thousands of dollars. Spare parts, as well as maintenance costs, can also be reduced.

The charts above show how this can be done. Suppose your water works now uses two 60 hp centrifugal pumps. Sometime in the future you plan to increase capacity by one-third by adding two more pumps which will operate in parallel. The total cost of the four pumps and motors installed would be approximately $26,000.

This same increase in capacity, in some instances, can be accomplished by multi-speed pumping. If you initially made the proper provisions, you could later increase the speed of the two pumps from 720 rpm to 900 rpm. This would give you the necessary capacity increase of 33⅓%. And the total cost would be only $21,000, a saving of $5,000 or approximately 20%.*

It's not necessary to limit your thinking to two-speed operation. Possibly the most economic proposal for your system would be three or four-speed operation. All public water-supply systems are different and pumping equipment is affected by different capacities, suction conditions, and static and friction heads. Therefore, all factors must be known before deciding on the proper approach. This sort of planning, however, combined with the use of multi-speed pumping when appropriate, can save you large amounts of money.

Ask your consulting engineer about the merits of multi-speed pumping. He'll explain to you its many advantages. And for unbiased equipment recommendations, get in touch with Worthington. Worthington makes all types of pumps and drives and a complete line of engines, compressors, and auxiliary equipment.

For a reprint of an engineering discussion of multi-speed pumping for water works, write to Worthington Corp., Section 105-4, Harrison, N. J. In Canada: Worthington (Canada) Ltd., Brantford, Ont.

*Cost figures are estimated and conservative. No cost has been added for additional space required by the extra pumps.

WORTHINGTON

Painter applies Torex Heavy with short-nap roller. Torex Heavy is a gray, rubber-base coating, giving 2.0 mil thickness per coat, with a flat finish. Imparts no taste or odor to water.

# STEEL BASINS IN BRISTOL, CONN.'S FILTER PLANT

## painted with Inertol® to lick rust problem

Solid protection and lower maintenance costs—these were the paint qualities that the Bristol Water Department sought for its 5 MGD filter plant. The Department chose Inertol Company's Torex® Heavy for its durability and superior resistance to rust, chemicals and abrasion.

After sandblasting to gray metal, the walls and floors of the coagulating and settling basins were immediately primed with Torex Rust-Penetrating Primer. Three coats of Torex Heavy were next applied. The basins were then ready for years of maintenance-free service.

Mr. J. L. Bean, Managing Engineer of the Bristol Water Department is highly pleased with the performance and appearance of Torex Heavy. Says Mr. Bean, "We just drained the north basin for inspection. Torex Heavy is doing an excellent job of rust prevention. We found the same good results in our inspection of the south basin."

Year after year consulting engineers, municipal authorities and maintenance men specify Inertol protective-decorative coatings. A paint best suited for *your* problem can be selected from Inertol Company's complete line.

Buy Inertol paints direct from manufacturer. Shipment within three days from our plant or from warehouse stocks in your area. Write for specifications on Torex Heavy on your letterhead, giving your title.

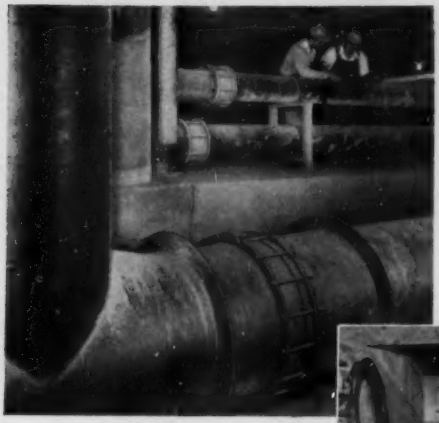
For our valuable maintenance painting guide with a handy selector chart, ask for free folder W587.

A complete line of quality coatings for water, sewage and industrial wastes plants and swimming pools.

Inertol® **INERTOL CO., INC.**

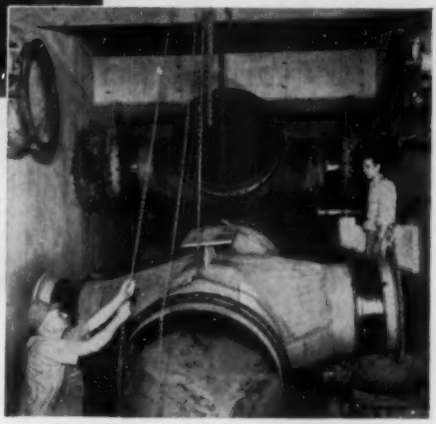
484 Frelinghuysen Ave., Newark 12, N. J. • 27-G South Park, San Francisco 7, Calif.

# Joining pipe the Dresser way...



## Always the easy way...

The 8-inch, 10-inch and 30-inch Dresser-Coupled lines illustrated here are part of the system used in servicing the Clague Road's advanced rapid-sand type filters.



## often the only way!

This battery of steel crosses is in the new Clague Road Filtration Plant, designed by Havens and Emerson, Cleveland, Ohio. The Plant will carry a normal flow of 50-million gpd. Contractor: Hunkin-Conkey Construction Company.

Dresser® Couplings provide the essential leeway for bolting up cross flanges to valves in tight spots. They'll take deviation caused by settling concrete and remain bottle-tight... permanently! Dresser's vibration-proof properties protect valves and other expensive equipment, and protect the pipelines, too. With a Dresser Coupling, two man-minutes per bolt gives you a permanent, leak-proof joint that absorbs expansion-contraction movement, keeps maintenance problems to a minimum, and makes repairs easier if and when they do become necessary. For a free copy of "Dresser Couplings for Filtration Plant Piping" and the Dresser Sewage Treatment Plants booklet, write to Dresser Manufacturing Division, Bradford, Pennsylvania.

**Bradford, Pennsylvania**
Chicago
Houston
New York
S. San Francisco
Toronto & Calgary

DRESSER
MANUFACTURING DIVISION

ONE OF THE DRESSER INDUSTRIES

# Last Look...

**BECAUSE CONCRETE CYLINDER PRESSURE PIPE MEANS VIRTUALLY NO MAINTENANCE**

You aren't likely to see *this* pipe again—because it's Concrete Cylinder Water Pressure Pipe, a product that's made to *stay* underground, silently, diligently serving future generations.

For example—a large midwestern city has never spent a maintenance penny on more than twenty million inch feet of Concrete Cylinder Pressure Pipe—while its total water pipeline repair costs have run into millions of dollars in the last ten years.

That's why water works operators say Concrete Cylinder Pressure Pipe is "as maintenance free as pipe can be"—one more good reason why you should contact Concrete Cylinder Pressure Pipe manufacturers in *your* area for your water pipe needs.

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION
228 N. LA SALLE STREET
CHICAGO 1, ILLINOIS

WATER FOR GENERATIONS TO COME

# PHOTOVOLT
## pH Meter Mod. 115

A full-fledged line-operated pH Meter of remarkable accuracy and stability at the low price of

**$175**

- SIMPLE IN OPERATION AND MAINTENANCE
- FAST AND DEPENDABLE IN SERVICE

*Write for Bulletin #225, also for literature on other Line-Operated and Battery-Operated Photovolt pH Meters*

## PHOTOVOLT CORPORATION

95 MADISON AVENUE NEW YORK 16, N. Y.

Also: Multiplier Photometers, Exposure Photometers for Photomicrography, Hemoglobinometers, Glossmeters, Polarimeters, Foot-Candle Meters, Interference Filters, Mirror Monochromators

# GRAVER BUILDS STANDPIPE FOR WATER EXPANSION PROGRAM

Part of a new $1½ million expansion program started last October by the Cuyahoga Falls, Ohio Water Department, is this new 750,000 gallon standpipe, designed, fabricated and erected by Graver. It stands 130′ high and provides water for the residents in eastern Cuyahoga Falls at a minimum of 50 pounds pressure. Graver craftsmanship and skill are nationally-known for fabricating standpipes, such as this, elevated water tanks and reservoirs. Call upon Graver for the solution to your water storage problem.

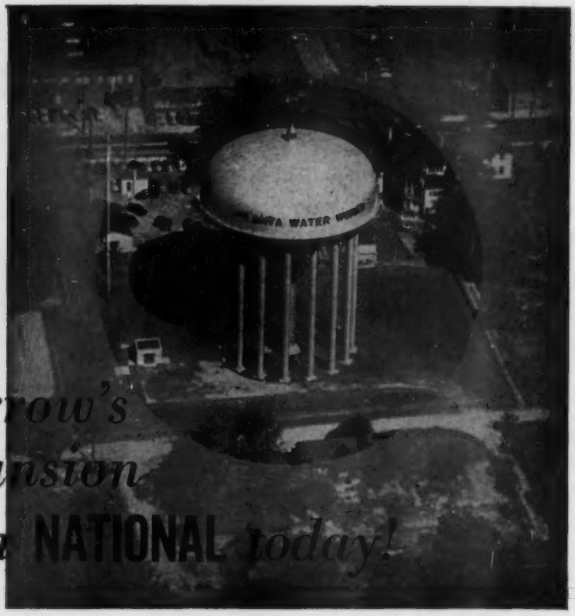
GRAVER TANK & MFG. CO.

EAST CHICAGO, INDIANA

DIVISION—UNION TANK CAR COMPANY

*Plants and Offices Across America*

GRAVER



*For tomorrow's expansion call in* **NATIONAL** *today!*

**Like Atlanta, Ga., *you* too can meet tomorrow's increased water demands with *clean water mains*. When the coefficient of sections of Atlanta's 45 year old main dropped to a low of 44, Waterworks General Manager, Paul Weir ordered National cleaning. Results were outstanding. Water pressure and capacity doubled, giving better fire protection and higher water pressure to outlying sections.**

**Do as other leading cities have done—let *National* cleaning provide for tomorrow's expansion without capital expenditure today! We can prove that National cleaning is an investment—not an expense.**

***Write us today!***

**NATIONAL WATER MAIN CLEANING COMPANY**

**50 Church Street • New York, N. Y.**

**333 Candler Building, Atlanta 3, Georgia; 920 Grayson St., Berkeley, Calif.; 115 Peterboro St., Boston 15, Mass.; 533 Hollis Road, Charlotte, N. C.; 8 S. Dearborn St., Rm. 808, Chicago 3, Ill.; P. O. Box 385, Decatur, Ga.; 2024 Merced Ave., El Monte, Calif.; 315 N. Crescent St., Flandreau, South Dakota; 3707 Madison Ave., Kansas City, Missouri; 200 Lumber Exchange Bldg., Minneapolis 1, Minn.; 510 Standard Oil Bldg., Omaha 2, Nebraska; 2910 W. Clay Street, Richmond 21, Va.; 502 West 3rd South, Salt Lake City 10, Utah; 204 Slayton St., Signal Mountain, Tenn., 424 S. Yale Avenue, Villa Park, Illinois; 7445 Chester Avenue, Montreal, Canada; 576 Wall Street, Winnipeg, Manitoba, Canada; Apartado de Correos No. 5, Bogota, Colombia; Apartado 561, Caracas, Venezuela; P. O. Box 531, Havana, Cuba; Marquinaria, Apartado 2184, San Juan 10, Puerto Rico; Bolivar 441-A, Marafi., Lima, Peru**

# USE NORTHERN GRAVEL
## for
# RAPID SAND FILTER

**FILTER SAND SPECIFICATIONS** are carefully laid out. The Effective Sizes and Uniformity Coefficients used by Consulting Engineers and also recommended by the American Water Works Association are the result of long years of research and experience.

The Northern Gravel Company is equipped to give you prompt shipment whether it be one bag or many carloads, exact to specification. Filter sand can be furnished with any effective size between .35 MM and 1.20 MM.

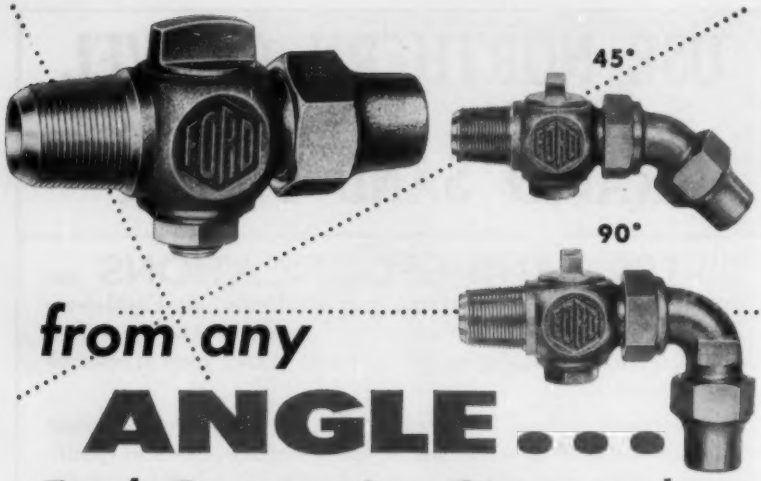
**CHEMICAL QUALITY** of the filter sand is also important. It must be hard, not smooth and free of soluble particles. This requires perfect washing, and grading facilities. We have every modern device for washing, drying, screening and testing.

**FILTER GRAVEL** supporting the Filter Sand Bed must be, in turn, properly graded to sizes calculated to support the Filter Sand, and be relatively hard, round and resistant to solution.

The new Northeast Station in the City of Detroit, recently completed, is one of the major projects included in the water department's expansion program. The Northern Gravel Company furnished 120 carloads of filtering materials for the 48 rapid sand filters incorporated in this plant.

Northern Gravel has no equal in facilities and our reserves of both sand and gravel are inexhaustible. Northern Gravel Company has been in business over 40 years. We guarantee uniformity of products and our records enable us to duplicate your requirements on short notice. Our location is central and we have commodity rates in every direction.

**NORTHERN GRAVEL COMPANY**
**Muscatine, Iowa**
**P.O. Box 307** **Phone: Amherst 3-2711**




from any
ANGLE . . .

## Ford Corporation Stops make easier installation and service

They are heavy and substantial, made of the finest waterworks bronze with accurate and carefully machined threads. Broad flats on the keys are easily turned with a wrench. Outlets are made for flare type connection to copper tubing.

**F-600 CORPORATION STOPS—AWWA standard threads at inlet. Available in sizes ⅝", ⅝" x ¾", ¾", and 1".**

**F-700 CORPORATION STOPS — American National pipe threads at inlet. Available in sizes ¾" and 1".**

All Ford Corporation Stops are shipped in special cartons to protect against damage and dirt.

A real convenience in handling, storing and taking inventory.

***Prices will be gladly quoted. Include model number, sizes and quantities.***

**THE FORD METER BOX COMPANY, INC.**
**Wabash, Indiana**

FOR BETTER WATER SERVICES

FORD

*Architect and Engineer: J. N. Pease & Company, Charlotte, N.C.*

**For permanence and beauty in its newest waterworks building . . .**

## Charlotte, N.C., chose panels of precast concrete

For their new $4,000,000 Hoskins Filter Plant, the Charlotte Water Department used decorative precast concrete panels attached directly to the building's concrete frame.

The panels, with exposed aggregate, give a pleasing combination of color and texture, and will last a lifetime. In addition, the use of precast panels saved construction time.

Architects everywhere are using concrete for its permanent architectural beauty, achieved with real, practical economy. Write for free literature on precast panels. Distributed only in the U.S. and Canada.

**PORTLAND CEMENT ASSOCIATION**
Dept. A11-78, 33 West Grand Ave., Chicago 10, Illinois
*A national organization to improve and extend the uses of concrete*

# GOT ALTITUDE VALVE TROUBLES?

## G-A *Cushioned* Altitude Control Valve

Your head will be in the clouds when a Golden-Anderson Altitude Control Valve takes charge of the water level in your elevated tank. From its protected spot in an underground pit this valve constantly maintains the water level and prevents overflow.



*Sizes 2" to 36". Pressures up to 250 psi.*

**Write today for Bulletin W-4B.**

GOLDEN ANDERSON *Valve Specialty Company*

1211 RIDGE AVENUE, PITTSBURGH 33, PA.

*Designers and Manufacturers of* VALVES FOR AUTOMATION

# New Nalco Coagulant Makes Bigger, Heavier Floc . . . Faster

## Nalcolyte 110 boosts Capacity of existing Treatment facilities

Nalcolyte 110 is a new, non-ionic organic coagulant of high molecular weight—over 1,000,000. It is used with conventional coagulants such as sodium aluminate and alum to increase size, density and uniformity of the floc.

**May be used in public water supplies**

Approved by the U. S. Public Health Service Technical Advisory Committee for use in treatment of public water supplies, Nalcolyte 110 speeds formation of tough, high-density floc as shown in the photos at right. In this case a single ppm of Nalcolyte 110 replaced 30 ppm of a conventional coagulant . . . *and produced a clearer water.*

**Greater Capacity; Better Water**

Small dosages of Nalcolyte 110 produce a fast-settling floc that permits increased throughput without danger of carryover and plugging of filters. If your problem is to produce clearer water, and more of it, Nalcolyte 110 is the newest, most feasible answer.

**Full Data Available**

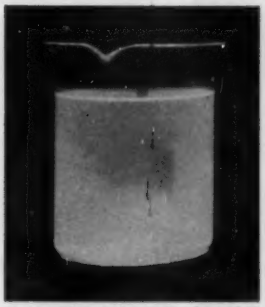
Write or call for details on this new, potent coagulant today . . . for better flocculation . . . greater capacity . . . lower costs.

*National Aluminate Corporation is now*

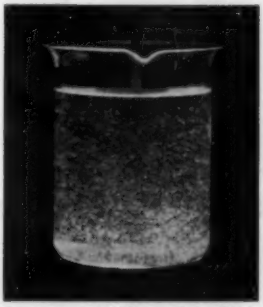
**NALCO CHEMICAL COMPANY**

**6315 West 66th Place Chicago 38, Illinois**

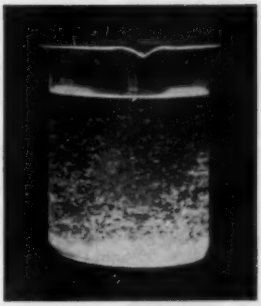
*In Canada: Alchem Limited, Burlington, Ontario*



Untreated control sample of a turbid raw water.



Same water with 50 ppm alum added, photographed 7 seconds after ceasing agitation.



Same water with 20 ppm alum and 1 ppm Nalcolyte 110 added. Photo 7 seconds after stopping agitation shows rapid settling rate of larger, denser floc.

Nalco® . . . Serving industry through Practical Applied Science

Nalco CHEMICALS

# LAYNE-the only complete water service organization

## COMPLETE SERVICE

## MEANS UNDIVIDED RESPONSIBILITY

In an age of specialization there is a definite advantage in doing business with a company offering a COMPLETE SERVICE. Only Layne, with over 75 years of experience and backed by Layne Research, can offer its customers this complete water service.

Layne

**LAYNE & BOWLER, INC., MEMPHIS**

*Offices and Factory • Memphis 8, Tenn.*

LAYNE ASSOCIATE COMPANIES THROUGHOUT THE WORLD

CONVENTIONAL 18-FOOT CAST IRON PRESSURE PIPE

GRIFFIN-20 COUNCIL BLUFFS

10% FEWER JOINTS!

CUT PIPE INSTALLATION COSTS WITH

GRIFFIN 20*

CAST IRON PRESSURE PIPE IN 20-FOOT LENGTHS!

"Give us longer pressure pipe lengths to help hold down rising labor costs involved in pipe installation!"

That was the overwhelming demand of water works operators, city engineers, consultants, and piping contractors in the Plains States, according to market surveys conducted by the Griffin Pipe Division of Griffin Wheel Company.

To answer this need, Griffin has developed the **Griffin-20** . . . a complete line of 20-foot cast iron pressure pipes in the popular 4- to 12-inch diameter size range. Compared to conventional 16-foot and 18-foot lengths, this modern 20-foot length means *over 10 percent fewer joints* . . . and *that* means that less time is required to install **Griffin-20** cast iron pressure pipe!

Griffin is the first American foundry to manufacture cast iron pressure pipe in 20-foot lengths, cast by the Delavaud process in this popular size range. A complete selection of pipe joints is offered, including the patented Bell-Tite *slip-on, mechanical joint,* and *bell and plain end.* All pipe will be either cement-lined to full specification thickness, or half thickness, as required.

Not only will the new *length* save money for cast iron pressure pipe users throughout the Midwest . . . the strategic location of the Griffin Pipe plant at Council Bluffs will also effect substantial savings in *shipment* time and money!

Take advantage of all these economies. The *next* time you have a cast iron pipe installation . . . *contact Griffin!*

*"Griffin-20" is a trademark of Griffin Wheel Company

GRIFFIN PIPE DIVISION

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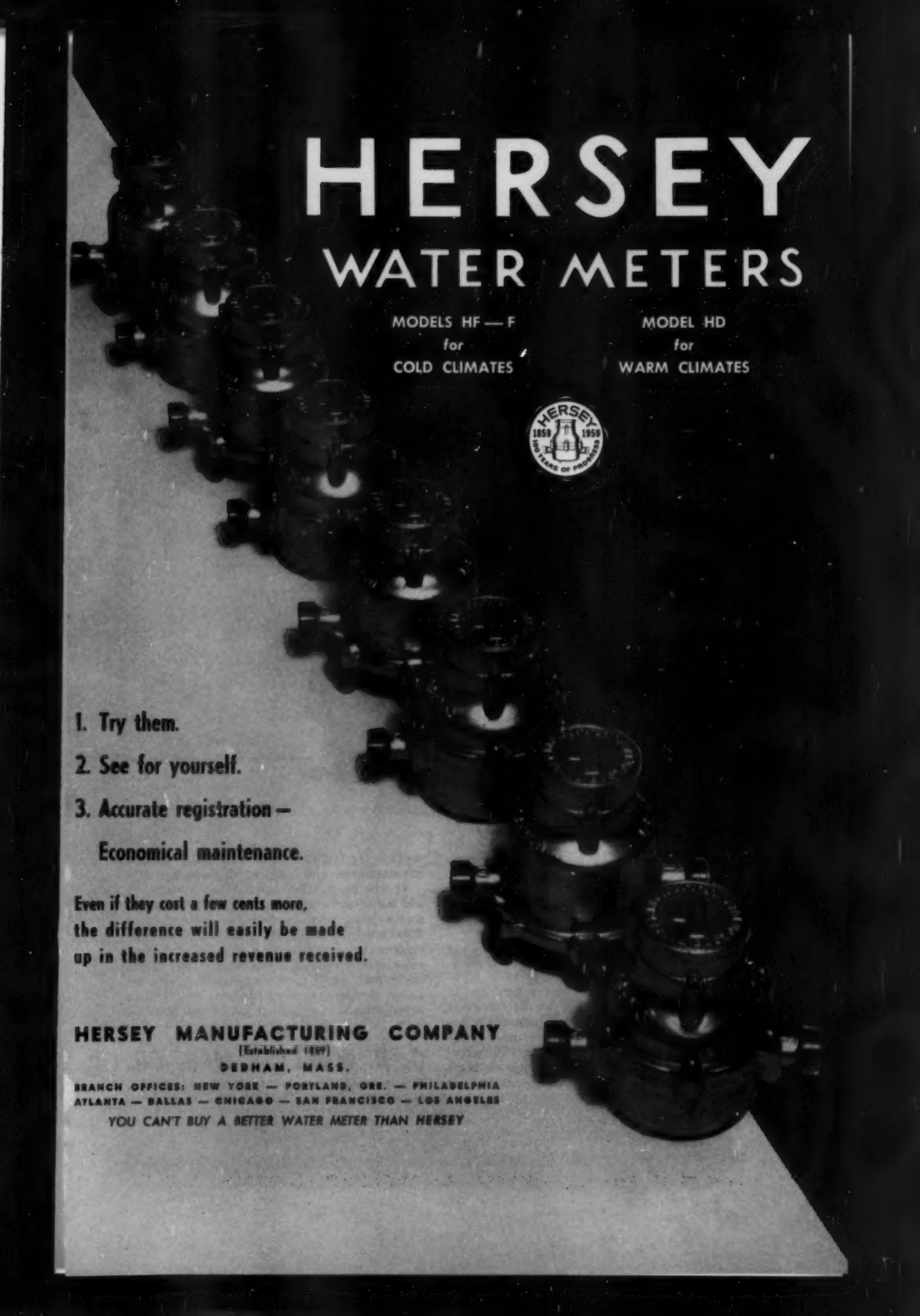
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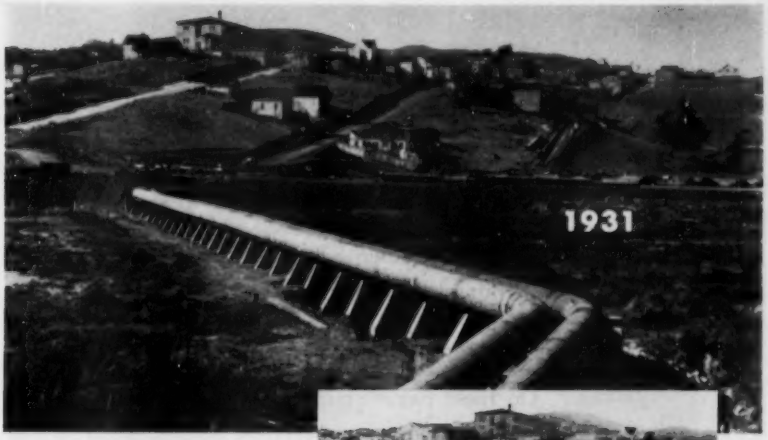

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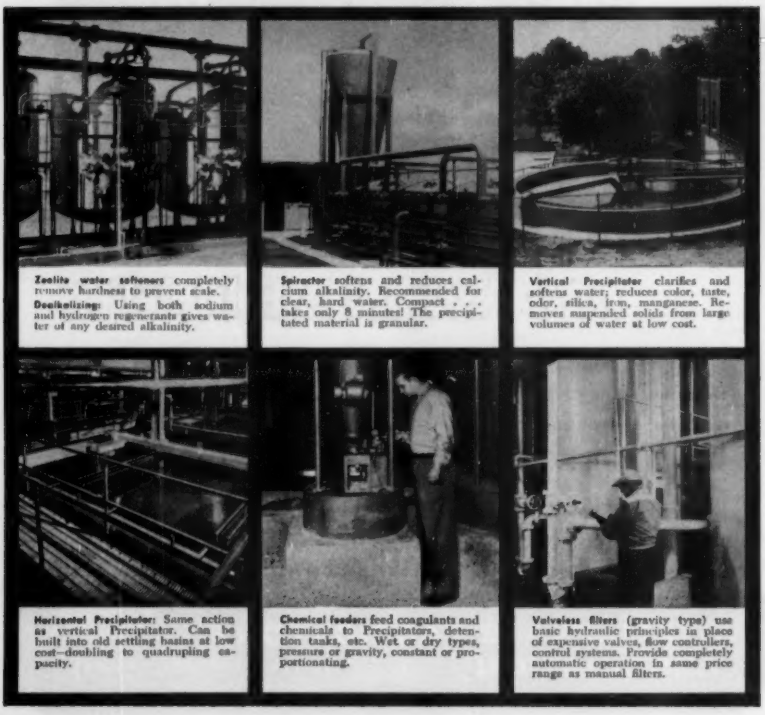

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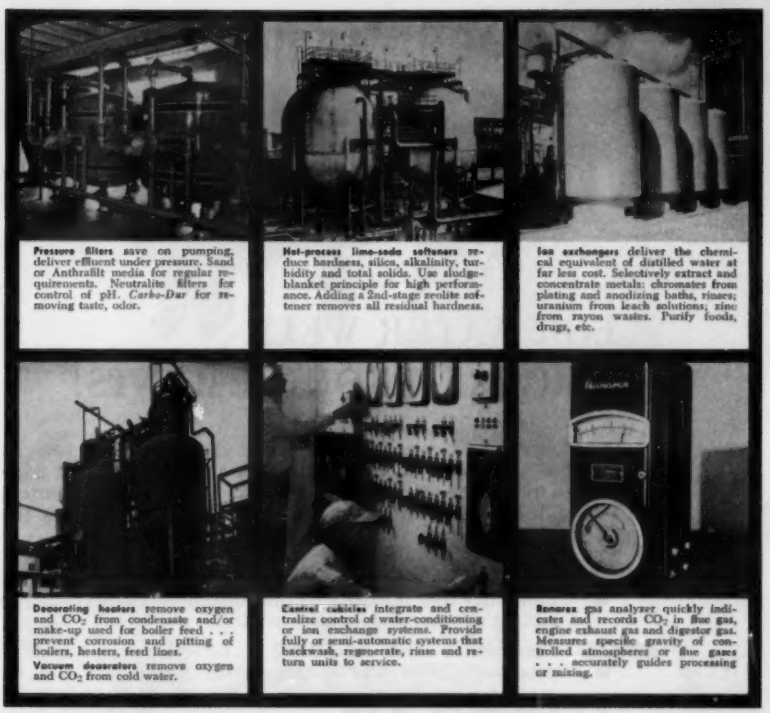
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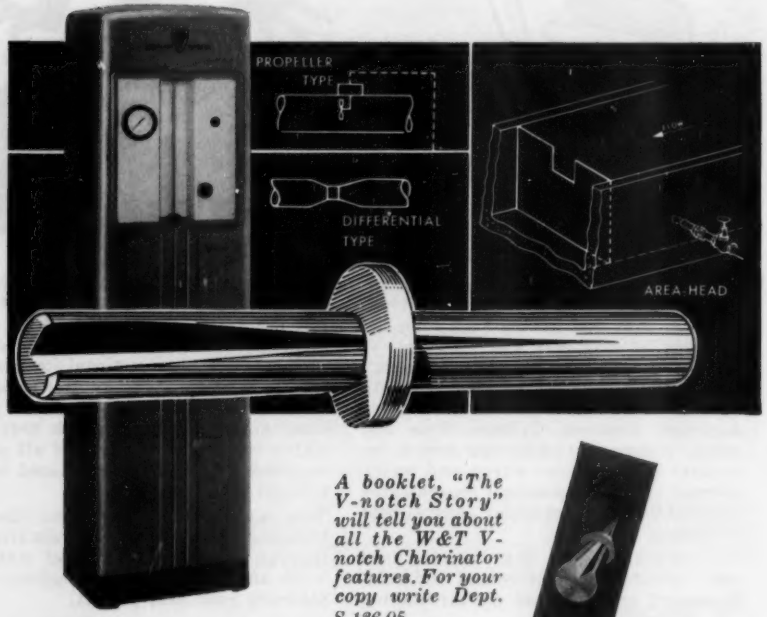


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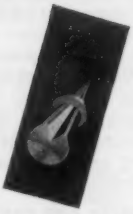

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Journal

AMERICAN WATER WORKS ASSOCIATION

VOL. 51 • NOVEMBER 1959 • NO. 11

# Regional Water Supply Systems

## *Joint Discussion*

*A joint discussion presented on Jul. 14, 1959, at the Annual Conference, San Francisco, Calif.*

## System Developed by Central City

***Wilford W. DeBerard***

*A paper presented by Wilford W. DeBerard, Deputy Comr. for Water & Chief Water Engr., Chicago, Ill.*

THE Chicago water system in 1958 supplied 57 suburban municipalities and miscellaneous unincorporated areas outside the city. These had a total population of 805,000 and used an average of 110 mgd, about 11 per cent of the system's average pumpage of 1,006 mgd. Another suburb began to use Chicago water early in 1959, and, at present, contracts are being negotiated for supplying four more suburban municipalities and municipal corporations.

Chicago began supplying water to suburban customers after the Sanitary District Act was passed by the Illinois legislature in 1889. This act requires Chicago to supply water on request at its city limits to any municipality or municipal corporation located within the confines of the Metropolitan Sanitary District of Greater Chicago. Charges for this water, the consumption of which is metered, must be made at rates no higher than those for Chicago customers.

### Growth of Chicago System

In 1909, the village of Burnham was the first suburb to be supplied by the Chicago system. In 1920, the total population of the suburbs supplied was 140,250; in 1930, 305,600. In 1940, 37 suburbs with a total population of 363,000 were supplied; in 1950, 48 suburbs with 522,000; in 1953, 51 suburbs with 598,000; and in 1958, 57 suburbs with 805,000.

The Chicago system in 1958 supplied a total area of 370 sq mi, of which 146 sq mi was outside the city limits. When the Sanitary District Act was

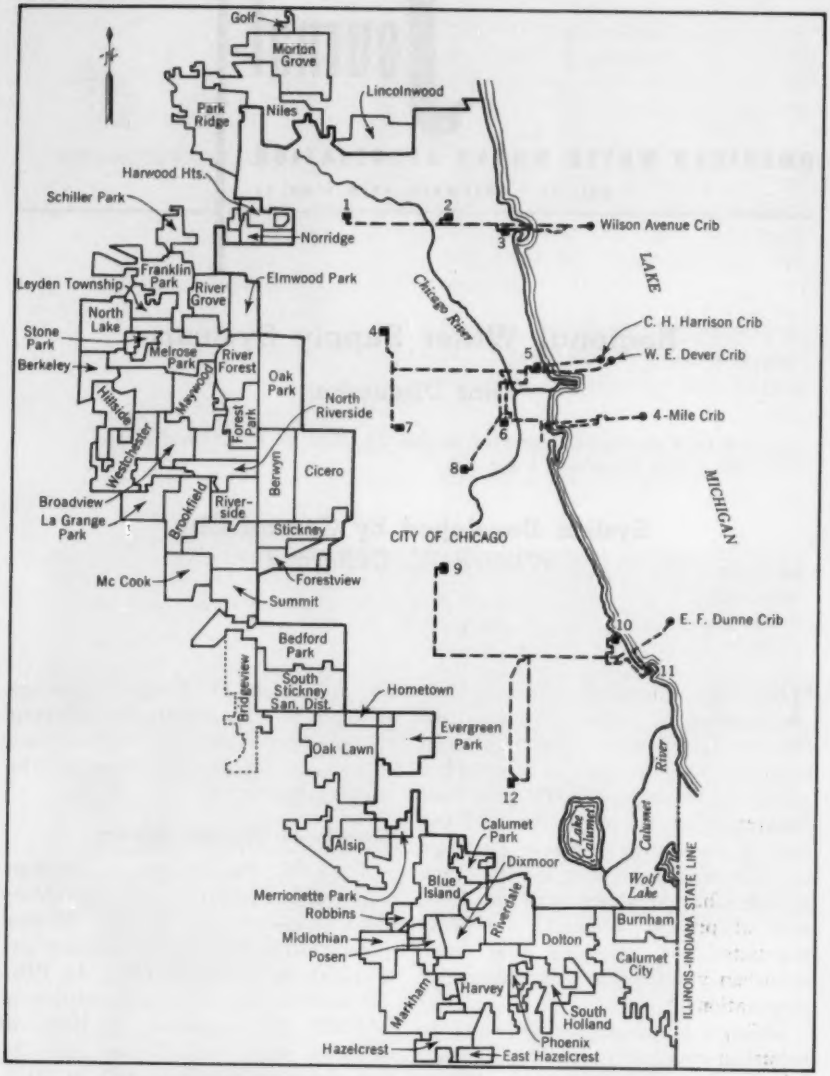


**Fig. 1. Municipalities Supplied by the Chicago Water System in January 1959**

*The numbered black squares represent pump station facilities in the city of Chicago: [1] Mayfair, [2] Thomas Jefferson, [3] Lake View, [4] Springfield Avenue, [5] Chicago Avenue, [6] Cermak, [7] Central Park, [8] 22nd Street, [9] Western Avenue, [10] 68th Street, [11] South District Filtration Plant, and [12] Roseland pump stations.*

passed, the total area of the district comprised 185 sq mi. By repeated annexations, the sanitary district's area grew to 358 sq mi in 1903; 386 sq mi in 1913; 500 sq mi in 1955; and 920 sq mi in 1957. Its total area now comprises approximately 97 per cent of the total area of Cook County, in which Chicago is located. This area, for which Chicago is obligated by the Sanitary District Act to furnish a lake water supply when requested, has more than doubled in the last 10 years.

During the early development of the suburban communities in the Chicago sanitary district, an ample ground water supply was available from deep sandstone wells and from shallower wells in the Niagaran limestone strata. As these communities become more populous and used more water, the once-static water levels dropped, particularly in the sandstone wells, to as low as 500 ft below ground surface, and much lower when the wells were being pumped. The more populous communities adjacent to the Chicago city limits, such as Cicero, Oak Park, and Berwyn, were among the first to take advantage of the provisions of the Sanitary District Act, in order to obtain a lake water supply. Other communities, as their well supplies became inadequate, requested Chicago lake water.

Of the 58 suburban communities now supplied by Chicago (Fig. 1), 45 receive their water directly from Chicago at the city limits. Water is resold by some of these communities to twelve others located beyond them: part of Bridgeview gets its supply from the South Stickney Sanitary District; Golf, from Morton Grove; La Grange Park, from Brookfield; Midlothian, from Robbins and Blue Island; Hazelcrest, Markham, Dixmoor, Phoenix, and Posen get their supplies from Harvey; Stone Park, North Lake, and Leyden Township get their supplies from Melrose Park. One community, East Hazelcrest, is supplied by a main owned by the Illinois Central Railroad.

### Inadequacies

At present, service to the suburbs is on the basis of bulk sale at the Chicago city limits, at the same rates as paid by customers in Chicago. Transportation, storage, pumping, distribution, and customer service are handled by the individual municipalities. Chicago is determined to have its suburbs carefully design their water facilities, so that their present and future needs will be insured. The contracts for suburban water supply specify the requirements for storage facilities and sanitation. Often in the past, because of limited funds, the suburbs installed inadequately sized water mains, reservoirs, and pumping facilities, which, because of rapidly expanding populations and resulting increased water demands, had to be replaced in a few years with larger facilities. There have been instances when new facilities were known to be inadequate even before they were completed.

The hot and dry summer weather in 1953 and 1955 hit new records. With the increased demand for water that resulted, particularly in areas where large numbers of new homes had been constructed, the inadequacies of suburban water systems supplied by Chicago became markedly apparent. The suburbs have grown very rapidly during the years after World War II, and in many places nothing has been done to enlarge the water systems to meet the needs of expanding populations. Also, many of the suburban communities depending on ground water supplies suddenly found them inadequate for increasing demands.

**Plans for Improvement**

It became apparent, because of limited quantities of ground water, that if the expanding metropolitan area of Chicago was to have an adequate water supply, it would have to come largely from Lake Michigan water. It was proposed to have the supplies handled by authorities like the Metropolitan Sanitary District of Greater Chicago or by the various counties. The governor of Illinois appointed a Northeastern Illinois Metropolitan Area Local Governmental Services Commission to study the problems and needs of the Chicago metropolitan area. In 1957, this organization was made, by Illinois state legislation, into the permanent Northeastern Illinois Metropolitan Area Planning Commission.

In 1954, the city retained a prominent engineering consulting firm to make an extensive study of the water supply needs of Chicago and the suburbs it serves, as well as the needs of other communities in the metropolitan area, for 25 years into the future. The study reviewed Chicago's plans for future utilities and determined the number of additional facilities that would be required should other communities in the metropolitan area need Chicago water. The report, which was received in September 1955, arrived at the following general conclusions:

1. A total of 85 communities in the suburban area surrounding Chicago—extending 20–30 mi outside the city limits, as far west as the Fox River—were getting their water from wells. Before 1980, 34 of these communities would need lake water for their supplies.

2. If all the communities in the metropolitan area were immediately to take water from the Chicago system, only 15 per cent of the total Chicago pumpage would be required to supply their needs (11 per cent was used by suburbs in 1958).

3. If, by 1980, the entire metropolitan area were to be supplied with Lake Michigan water, the total supply taken would not exceed 25 per cent of Chicago's total pumpage. Inasmuch as only 34 of the 85 municipalities using well supplies would be likely to request water service from Chicago, the total lake water supply required for the metropolitan area in 1980 would probably not exceed 18 per cent of Chicago's total pumpage.

4. If the proper legislative authority were obtained, Chicago could finance and construct outside the city limits the express feeder mains and booster stations that would be required to deliver water to reservoirs serving groups of municipalities in the metropolitan area. These municipalities could then distribute the water through their own systems. Chicago could recover the costs of construction, operation, and maintenance of the outside facilities by a charge added to the base rates for the delivery of water to the city limits. Four transmission lines could supply the suburbs—located along the routes of the lines—that were likely to request the lake water service: Arlington Heights, Elmhurst–Lombard, La Grange–Western Springs, and Chicago Heights–Forest Park lines.

5. In the entire region, only Chicago had the financial resources and organization needed to construct, operate, and maintain the water supply facilities for so large a metropolitan area. Chicago also had an experienced engineering staff to deal with the various problems involved.

On the recommendation of the Northeastern Illinois Metropolitan Area Local Governmental Services

Commission, the state legislature, in 1957, passed two enabling acts that permitted Chicago to construct facilities up to 35 mi beyond its corporate limits. Although the legislature still required that the water rates charged at the city limits for the suburbs located in the Metropolitan Sanitary District of Greater Chicago could not be higher than those charged to Chicago customers, an additional rate charge was permitted to compensate for the cost of financing the operating facilities constructed outside the city limits.

Since this report was received, the number of suburbs supplied by Chicago at the city limits has increased from 51 to 58. As mentioned before, negotiations are now in progress for serving four more. With regard to conclusion No. 4 of the consultants' report, two suburban groups are now planning to obtain a lake water supply. The Arlington Heights group—consisting of Des Plaines, Arlington Heights, Mount Prospect, and Palatine—or what is now called the DAMP Commission, is in the process of studying various plans for obtaining lake water. Included is a proposal that Chicago, as well as the commission, build an express main to the city limits. The other group, composed of Elmhurst, Lombard, and Villa Park, has formed a commission that plans to build its own lake water system by obtaining water from an intake in Lake Michigan at Glencoe, Ill. Temporarily, this project has been delayed because the Great Lakes states have threatened to take court action to stop lake water diversion to another watershed.

## Conclusion

Chicago has embarked on an extensive capital improvements program for water utility construction. The city is attempting to provide not only for its own needs and for the needs of suburbs it now serves, but also for the needs of suburbs that may be added to the metropolitan area during the next 25 years. Since 1953, a total of $104,185,000 has been expended, and present plans call for additional construction totaling $128,000,000 for the period 1959–1963.

The philosophy adopted by Mayor Richard J. Daley and the present administrators of the Chicago water system is, in effect: What is good for the Chicago metropolitan area is good for Chicago. They are confident that Chicago is in the best position to supply adequate lake water service at the lowest cost to any of the suburbs in the metropolitan area.

## Acknowledgment

The Department of Water and Sewers of Chicago is headed by Commissioner James W. Jardine. The staff directly concerned with suburban water supply planning is headed by H. H. Gerstein, assistant chief water engineer; J. T. Garrity, general superintendent of water distribution; and E. Edelstein, engineer of water distribution.

## System Developed by District Authority

*John W. McFarland*

*A paper presented by John W. McFarland, Gen. Mgr., East Bay Munic. Utility Dist., Oakland, Calif.*

The East Bay Municipal Utility District (EBMUD), Oakland, Calif., has been responsible for a metropolitan area water system since 1923.

The first settlements on the eastern shores of San Francisco Bay were founded in the 1840's. Among them were San Antonio, Contra Costa, Clinton, and Lynn. By 1852, the settlement of Contra Costa had grown more rapidly than the other settlements and had been incorporated into the city of Oakland. From that early date through the late 1920's, the problem of water supply was a major issue in this city, as is evident from old records, such as newspaper clippings and water company files.

Although rainfall in the East Bay area was insufficient for an adequate water supply, no provision was made for storing the water available from local creeks and streams. In the early days, the scramble for franchises, the political intrigue, and personal chicanery rarely solved the water problems of the growing population, but often added to them.

Anthony Chabot, the "water king," was responsible for the first water to actually flow through pipelines in the city of Oakland in April 1867. His Contra Costa Water Co. was the first to deliver water to customers. From that date forward, many small companies came into existence. They were operated for short periods, then were dissolved or consolidated with other companies, until in 1916 the East Bay Water Co. was formed, comprising a total of seventeen original companies. The water supply of the East Bay Water Co. was taken from local creeks impounded principally by the San Pablo, Upper San Leandro, and Chabot dams.

As early as 1876, the Oakland *Tribune* published a truly prophetic editorial commenting on the supply and condition of the water. This editorial blamed circumstances not on the local water company but on local sources of supply. It declared that the community needed sources in the Sierras. Water shortages eventually forced the residents of the ever expanding East Bay cities to realize that new watersheds must be found. Finally, in 1921, an act of the California legislature permitted the formation of a publicly owned agency that could service both incorporated and unincorporated territories and could extend into more than one county. This act, known as the Municipal Utility District Act of 1921, paved the way for the formation of the EBMUD, which encompasses the principal cities of the East Bay located in both Alameda and Contra Costa counties.

An election actually authorizing the formation of the EBMUD was held in May 1923. Nine cities originally served by the East Bay Water Co. voted to form the district. These cities were Alameda, Albany, Berkeley, El Cerrito, Emeryville, Oakland, Piedmont, Richmond, and San Leandro. The area served at that time was 93 sq mi.

### Powers and Organization

EBMUD has broad corporate powers: it has the right of eminent domain and the power to enter into contracts; it can acquire, hold, and sell property; it can acquire, construct, and operate facilities for supplying water and for sewage disposal; it can incur indebtedness and issue bonds within specified limitations; it can invest surplus money and levy and collect taxes.

The government of EBMUD is vested in a board of five directors, each representing a geographic ward, although each is elected by the voters at large within the entire district. The directors are chosen at general elections and serve 4-year terms, staggered between three and two directors. Their compensation is $20 per meeting attended, not to exceed two meetings per month.

The board is the legislative body of EBMUD and determines all questions of policy. It decides rates, rentals, charges, and personnel classifications, and makes and enforces regulations, contracts, practices, and schedules. The board appoints a general manager, accountant, secretary, treasurer, attorney, and such assistants to these officers as are deemed necessary to administer the affairs of the district.

### Growth

Immediately after the formation of EBMUD, an engineering survey of the water problem was begun. This study was conducted under the direction of Arthur P. Davis, first chief engineer and general manager of EBMUD. He and his associates, William Mulholland and George W. Goethals, proposed the Mokelumne River as a source of water for the district. The watershed for the Mokelumne River covers about 575 sq mi in the Sierras, about 150 mi east of San Francisco Bay. This source was approved as the most feasible, and a bond issue of $39,000,000 was authorized by the voters in November 1924 to acquire the necessary rights for water and to construct the Mokelumne project. Hearings were begun on water rights applications. Specifications were written for the construction of Pardee Dam on the Mokelumne River, about 38 mi northeast of Stockton, and for an aqueduct to bring water about 90 mi to the East Bay area. In 1925, construction actually began.

Before the Mokelumne project was completed, another bond issue for $26,000,000 was authorized by the voters in 1927 for the purpose of acquiring the distribution system of the privately owned East Bay Water Co. By December 1928, this acquisition was accomplished, and when water finally flowed from the Mokelumne into the East Bay in June 1929, all phases of the East Bay water system were publicly owned by one agency.

Since that time, the area served by EBMUD has expanded tremendously by annexation. Originally, only nine cities made up the area; now there are thirteen incorporated cities. Originally, an area of only 93 sq mi was served; now EBMUD serves about 225 sq mi, including a large extent of unincorporated territory in both Alameda and Contra Costa counties. And still the district has not reached the end of its growth. EBMUD plans to expand further into an area that will eventually encompass more than 400 sq mi. To make this possible, additional water rights to the Mokulumne River have been acquired, and additional financing of $252,000,000 worth

of bonds was approved by the voters in June 1958. Work has already begun on a 10-year construction program that will cost $283,000,000. The real challenge is to keep supply greater than demand.

The growth of EBMUD is controlled by its board of directors. After new applications for service are received, annexation of additional territory requires either an affirmative vote of the people from the area desiring annexation, or a petition of all the property owners in the area. In either instance, the board of directors gives the final approval.

**Construction Program**

The 10-year construction program is designed to make possible a 350-mgd water supply. The program includes the following projects:

*Mokelumne development—cost, $42,338,000.* Two new reservoirs, Middle Bar and Comanche, will be constructed on the Mokelumne River. Middle Bar Dam and Power House will be built above the existing Pardee Reservoir; Comanche is to be located downstream from Pardee Dam. The Mokelumne development budget also includes funds for acquisition of land, rights of way, and easements.

*Mokelumne Aqueduct No. 3—cost, $68,233,000.* The third aqueduct to transport water from the Sierra reservoirs to the East Bay will be constructed on the same right of way as existing Aqueducts No. 1 and 2. Together with the two present aqueducts, it is designed to be capable of transporting all the available Mokelumne River water supply, 325 mgd. The steel pipeline will be 87 in. in diameter (Aqueduct No. 1 is 65 in.; Aqueduct No. 2 is 67 in.). The new aqueduct will be more than 80 mi long (not including connecting tunnels).

*Terminal reservoir storage—cost, $38,906,000.* An additional terminal reservoir will be constructed in the East Bay to augment the four local terminal reservoirs (San Pablo, Upper San Leandro, Chabot, and Lafayette), which store both the water from the Mokelumne aqueducts and the local rainfall runoff. These reservoirs enable EBMUD to maintain a 90-day reserve supply of water within the service area, and to store water for peak consumption periods. Also included in this project are pumping plants and aqueducts that will bring Mokelumne Aqueduct water to the terminal reservoirs, and aqueducts that will connect the terminal reservoirs to filter plants.

*Filter plants—cost, $14,105,000.* Filter plant capacity will be increased by more than 60 per cent with the construction of two new plants and the enlargement of two of the five existing plants. New plants will be located at El Sobrante and Walnut Creek. The capacity of the Upper San Leandro Filter Plant will be nearly tripled; the capacity of the Lafayette Filter Plant will be doubled.

*Filtered water reservoirs—cost, $26,781,000.* Distribution storage capacity will be increased from 500 mil gal to 818 mil gal with the construction of 81 new distribution reservoirs and tanks.

*Pumping plants—cost, $4,279,000.* Expansion of the EBMUD distribution system will include additional pumping plants and regulators throughout the system.

*Distribution mains—cost, $65,653,000.* New pipeline installations will increase the underground distribution system by 620 mi, an increase of 25 per cent

over the present 2,560 mi. In addition, 260 mi of substandard mains will be replaced.

*Service facilities—cost, $22,713,000.* Additions to EBMUD service facilities will include service buildings, service yards, and connecting lines and meters.

The total cost of construction will be $283,008,000; $31,008,000 will come from revenues. The remainder, $252,000,000, will come from a bond issue.

### Relationships and Administration

The preceding remarks have been devoted to a factual account of the growth and development of a district-type operation designed to meet the water needs of a metropolitan area. Of course, the real questions of interest are: how successful and desirable is such a type of organization, and how does it contrast with a municipal operation? In the discussion of these questions development by private companies is not considered. There certainly are instances where a privately owned company can and has done a good job in advancing metropolitan growth. It is assumed, however, that in this article it is more pertinent to compare the different ways that a publicly owned company can develop a supply system for a metropolitan area.

For the purposes of this presentation, and using the East Bay area as an example, a metropolitan area may be defined as a large geographic area composed of several incorporated cities. These cities, although separate entities, have, through a process of growth, become contiguous or so interrelated that it is difficult to distinguish where one jurisdiction ends and another begins. Such a metropolitan area must be defined as also including a large extent of unincorporated territory that may in the future become incorporated (wholly or in part), become amalgamated with other existing corporate cities, or remain indefinitely as an unincorporated area. In the latter instance, such an unincorporated area must of necessity be under the jurisdiction of a separate county government.

With regard to the East Bay area, which is dependent on surface supplies, it is difficult to imagine how the water needs could have been supplied by a method other than a district-wide operation. If each municipality owned and operated its separate water department, the result would be a completely unworkable system. Historically, this is borne out in part by the fact that in the East Bay, several private water companies had been combined into one company prior to the formation of EBMUD. Separate municipal development becomes even more impossible to conceive when it is necessary for a municipality to go a long way for its source of water supply. There is one municipality in the East Bay which continues to own and operate its water system. It is able to do so, however, only because a large metropolitan agency has developed a mountain source and makes a part of this source available. Otherwise, the municipality would be practically helpless to develop an adequate, distinct supply of its own. This situation suggests that separate municipal ownerships in a metropolitan area could be feasible if there were a large overlying and district-wide agency whose only function was to establish and make available to the separate municipalities a supply of water adequate to meet their needs. An exam-

ple of such an operation can be found in Southern California, where the metropolitan water district operates on this basis.

An argument in favor of the EBMUD system, whereby all the operations of water supply from source to customer are handled by one agency, is that it reduces the number of separate units engaged in a single basic function. Presumably, this system is more efficient and is able to adjust to changing conditions more rapidly than an operation that includes many units with uncommon problems which are dependent on a master unit. To demonstrate the truth of this statement it is necessary to examine the relationships and the administrative policies of EBMUD.

The relationships that exist between the EBMUD governing body and its individual customers and the other governing bodies within whose boundaries it must operate, are by their very nature political. Although it is the general policy of the district to keep water supply affairs out of politics, there are many political relationships that must be fostered if community growth is to be sustained.

As mentioned before, the area served by EBMUD includes thirteen incorporated cities, each with its own city council, and a large extent of unincorporated area in two counties, each with its own board of supervisors. Therefore, there are fifteen governing bodies represented by the board of directors of EBMUD. Each of these fifteen bodies is responsible for and has an interest in the health and welfare of its citizens, the growth of its community, orderly street and highway construction and maintenance, planning, zoning, and a reasonable tax structure—in effect, a harmonious, working community. Obviously, there are many possibilities for friction with such an arrangement. The elimination of friction is relatively simple in theory, a little more difficult in practice, for it requires that public relations receive constant attention. This means that the board of directors of EBMUD must become acquainted with the individuals who are governing the cities and counties of the East Bay; the board must show an interest in, and respond to, the needs of the communities and their governing bodies. The officers and various staffs of EBMUD must become acquainted with the many key personnel on the staffs of the cities and counties. District staffs must be willing to cooperate with city staffs, recognize their difficulties, and be aware that joint problems exist.

For example, a major responsibility of any city administration is the construction and maintenance of streets. It disturbs a citizen to know that it took months to repair a street that was torn up the following day so that a 6-in. main could be installed. Planning and coordination can prevent this. The EBMUD engineering department requests that all the district's cities and counties supply information on their street and highway programs. At the same time, the department makes information available regarding the major construction projects of EBMUD.

As a matter of course, EBMUD submits all its plans for construction within the counties or cities to the official planning staffs for review. In this way, the work of EBMUD can be made to be in harmony with the plans of the counties and cities. This procedure is followed although EBMUD, as a state agency with separate corporate powers, has the authority to make an

independent and final judgment in the interests of the general public.

It must be pointed out that for the individual municipalities, there may be one consequence of district-wide operation—a loss of revenue. Many municipalities that own their water systems use water department revenues to meet general obligations for the purpose of lowering taxes. This may not be good practice, but it is done. It is a practice that might make it very difficult in certain localities to institute a system of district operation, because municipalities would have to sacrifice some revenue. This factor, however, has never been a major argument against EBMUD. Harmonious relationships prevail in the district, primarily because service and water quality have been excellent. In addition, the tax rate imposed by EBMUD has been very modest. Water rates, compared to those of nearby communities, have been kept low, consistent with good operation, and have always allowed for community growth.

## Conclusion

With regard to financial matters, revenue for water development should come from an independent source and should not be used for other purposes. This is necessary to insure proper development and maintenance of a water supply. In communities where the development of water supply has been inadequate, the fault can usually be traced to an incomplete understanding of the fundamentals of public administration and finance.

The operation of EBMUD has proved satisfactory in the past and shows great promise for the future. It has aided the development and growth of the entire East Bay area, without causing administrative problems in the cities and counties under district jurisdiction. Whether or not this type of operation would be successful in other communities with water supply problems requires individual analysis. EBMUD's operation can, in any event, serve as an example of a successful water supply system developed by district authority.

# Consolidation of Water Systems in Califorina

*John C. Luthin*

*A paper presented on Jul. 14, 1959, at the Annual Conference, San Francisco, Calif., by John C. Luthin, Vice-Pres., Suburban Water Systems, La Puente, Calif.*

THE evolution of water service in California communities, which range from small, isolated towns to sprawling metropolitan areas, has taken many forms. Water supply is one of the most essential elements in the development of new areas, and water service of some sort usually becomes well established long before there is any recognition of the need for planning to meet future growth and expansion. The inability of many growing utilities to cope with expansion problems has caused them to be absorbed by more progressive utilities or to relinquish their water systems to more capable management.

Building distribution systems to serve new customers has not been the only problem, however. There are large geographic areas with many firmly established water utilities that have found that there was a widespread shortage that could not be satisfied by the many utilities acting individually. The natural reluctance of existing utilities to release their water systems to an overall agency often prevents a plan of consolidation from becoming a reality. In order to expedite the solution of California's water problems, many alternative courses have had to be contrived.

### Types of Utilities

Mutual water companies are nonprofit corporations organized to serve their own stockholders. As long as they furnish service only to stockholders and operate without profit, they are not regulated and need pay no income tax. Although most mutual water companies began as irrigation projects, many domestic systems are furnishing water service in communities and rural areas. There are about 1,000 mutual water companies in California; they serve approximately 5 per cent of the state's population.

Privately owned utilities are the only ones subject to regulation by the California Public Utilities Commission. Among other things, the commission defines service areas, sets rates, and establishes standards of service and rules and regulations with customers. There are about 480 privately owned water companies serving about 24 per cent of the state population.

More than 180 California cities operate their own water systems. In many cities, water service is looked upon as a service to the community and operation is integrated with other departments for functional efficiency. In other cities the service is provided as a proprietary function under appointed boards or commissions. Water service is often extended outside the city limits at premium rates as a means of obtaining additional revenue and controlling fringe areas and annexations.

### Types of Districts

There are several types of districts used to furnish water service to individual customers. A county water works district is designed for small operations and utilizes the county board of supervisors as its governing body, whereas other types are autonomous and elect their own boards of directors. There are many other types of districts, such as community service districts and irrigation districts, which may provide several services, including domestic water service. Some large districts have been created by special acts of the legislature.

TABLE 1

*Types of California Water Utilities and Population Served by Each*

| Type of Utility | Per Cent of Total Utilities | Per Cent of Total Population Served |
|---|---|---|
| Municipally owned | 11 | 58 |
| Privately owned | 26 | 24 |
| District | 8 | 13 |
| Mutual company | 55 | 5 |

In addition to the many districts serving individual customers there are at least eight types that have been designed to conserve and distribute water to the retailing utilities. For example, 28 of the 58 counties have organized flood control and water conservation districts, although many of these districts are inactive. These agencies usually serve large areas and overlie other water utility service areas. There may be as many as five districts overlapping or overlying a single area, all of them engaged in some form of water production and distribution.

Table 1 lists the types of agencies engaged in distributing water to the residential, commercial, and industrial customers and shows the relative numbers of, and population served by, each type of utility.

### Reasons for Consolidation

The three principal reasons for consolidation, integration, and unification of water utilities are the need for adequate financing, improvement of service, and the need for increased water supply. Weaknesses or deficiencies are not necessarily corrected by an increase in the size of the utility. Although consolidation to produce bigness may often be advantageous, it is not always a necessary step. Very often a change in ownership or management of a distressed utility can accomplish the same end as consolidation or merger with another utility.

The service rendered by any underfinanced utility inevitably deteriorates. The methods of financing of mutual companies, privately owned utilities, and municipal utilities are somewhat different, but the inability or failure of any type of utility to meet the capital requirements of expansion and replacement can stymie its growth. This has become very apparent in many areas of the state where growth is rapid and there is active competition between all types of utilities for new customers and for control of service areas. The ability to compete requires sound financial policies and the adoption of rules governing the extension of mains that will neither discourage development nor place an undue financial burden on the utility.

Utilities that are unable to meet the demand for satisfactory service soon outlive their usefulness. Water systems in large metropolitan and suburban areas must meet every requirement of good service, including adequacy of water supply, good quality of water, satisfactory pressures, and adequate fire protection. Poorly designed

systems that are unable to meet normal standards of service tend to retard the development of an area, reduce property values, and lead to revolt by the customers and community interests.

Inability or unwillingness to satisfy the public demands has led to many changes in California. Public interests are becoming more effectively served by increasing vigilance in the enforcement of service standards. The ever increasing review of water system design by regulatory bodies, health departments, and planning commissions helps to insure the provision of adequate service for the future. Fire protection is assured in new systems by a planning commission's review of subdivision maps and by the pressure exerted by fire protection agencies, insurance rating bureaus, the public, and industries. Improvements in water system design in recent years have done much to reduce the need for eliminating many small water utilities.

Some interesting and unusual situations which are peculiar to consolidation of utilities in cities have arisen in the Los Angeles area. In the past 10 years nineteen cities have been incorporated in the almost solidly populated area to the east and south of Los Angeles. The area is served by approximately 200 water utilities, and many of the newer cities are served by as many as twelve water utilities. Consolidation of such water utilities into a single, municipal water department has been proposed for many reasons, including the creation of an additional source of income to the city, improvement of service, control of rate making, and manipulation to attract new industries. Studies have indicated that, although this type of consolidation may have some advantages, it may also result in some ineconomies both to those inside and to those outside the city. Severance of the water utility systems at the city limits can create as many problems outside the city as it cures inside. The possibility of future annexations must also be considered. An example of this type of consolidation is under study by the city of Downey. This city with a population of 90,000 is served by two county water districts, three mutual companies, four privately owned utilities, and another city. One of the county water districts provides 45 per cent of the service and is wholly within the city. The problem of whether Downey can take over the district without payment, on the assumption that the public served would be the same and that there would therefore be no real change in ownership, is now being tested in court.

## Examples of Consolidation

The need for a larger or improved source of supply has been the primary reason for consolidation and unification of water utilities in California. The various devices used to accomplish the result can best be illustrated by examples.

### *Marin County*

The Marin Municipal Water District was organized in 1912 to provide unified water service to most of Marin County. The district has taken over the Sausalito municipal water system and more than fifteen public utilities, all of which had been utilizing springs, surface water, and wells as sources of supply. In general, the service had been poor and the sources of supply had been inadequate. The district integrated the service to nine cities and intermediate areas and developed surface water supplies within its area.

*East Bay Municipal Utility District*

The area on the east side of San Francisco Bay was originally served by at least eighteen public utilities. By 1916, all but one of these had been merged into one company, and the last was acquired by that company in 1921. The inability of the local sources of supply to provide for future growth led to the formation of the East Bay Municipal Utility District in 1923. The new district then undertook the construction of facilities to store and convey water from the Mokelumne River to the service area 90 mi away. The district acquired the single public utility and has, since 1928, furnished all water service to the individual customers in thirteen cities and in intermediate areas in two counties (*1*).

*San Francisco*

In 1930, San Francisco acquired the properties of a privately owned utility that had been serving all but a very small area that was being served by the city. The action was prompted by the need for additional water. The city developed a supply on the Tuolumne River and built 100 mi of aqueduct to transport the water. In addition to providing a water supply for itself, San Francisco now wholesales water to eleven cities, eleven districts, six public utility service areas, and two mutual water companies.

*Monterey*

The Monterey Peninsula has depended for many years upon the Carmel River and wells in the Carmel Valley as the only substantial sources of supply. Numerous water utilities that once served the Peninsula have been absorbed and consolidated together in the California Water and Telephone Co. The water service on the peninsula, including the cities of Monterey, Pacific Grove, and Carmel, are completely integrated. The company has constructed impounding reservoirs on the Carmel River, and this water, together with well water, is conveyed to the service area through many miles of transmission line.

*Los Angeles Area*

A unique situation exists in the Los Angeles metropolitan area. A somewhat complex composite of agencies is working collectively in the development and distribution of water. Historically the water supply for this area has been obtained from several basins which have provided an abundant ground water supply. The city of Los Angeles became the first community to develop an important supplemental supply when it constructed the Owens River project in 1914.

In 1929 the Metropolitan Water District of Southern California (MWD) was organized to bring supplemental water to the thirteen cities in the district at that time. Since 1942 ten areas have been annexed to MWD in the form of municipal water districts, each comprising relatively large areas. The feeder lines of the MWD form a grid system through most of Southern California and are extended into all annexed areas. MWD deals only with its member agencies, and these agencies either distribute water directly to customers or sell water to individual water utilities for distribution. MWD water is not only delivered to the retailing utilities, but it is also purchased through member agencies and spread for percolation into the overdrafted basins and to recharge basins by injection wells as a means of creating freshwater barriers to prevent salt water intrusion. The combination of deliv-

ery through pipelines and storage in the basins, if carried out to the ultimate desires, would provide a means of taking water from the Colorado River at a fairly constant rate of flow and of utilizing the local ground water basins as storage to meet seasonal and daily peak demands.

In order that the total costs for producing water may be equitably spread over all water production, some charge must be made for water pumped from the basin. Complete equality will be reached when all water producers pay a pumping charge that, together with normal operating expenses incurred in pumping, will equal the cost of purchasing MWD water directly. A modification of this program is already in effect in the West Basin, an area with a population of 600,000 served by sixteen utilities, where each producer is limited to an annual allotment of well water pumped in accordance with a stipulated agreement and court order. Producers needing less than their pumping allotment may sell the unused water at a price not to exceed that of MWD water to other producers through a pool administered by the State Water Master Service acting under court appointment.

The complexity of water conservation and distribution in the metropolitan area in Los Angeles County can be best illustrated by the program in effect at the central basin. This basin is southeast of the city of Los Angeles and is adjacent to and south of the western basin. This area, which has a population of 980,000 and is served by 90 utilities, organized the Central Basin Municipal Water District in 1952 and annexed to MWD so that water would be available to the water producers. In the meantime, the Los Angeles County Flood Control District enlarged its spreading grounds at the upper end of the basin for the percolation of flood waters. Special zones in the flood control district provide tax money to buy MWD water to be percolated through the same spreading grounds. A special replenishment district is now being organized to overlie the central and western basin municipal water districts and several cities and provide means for utilizing MWD water to recharge the basins. This pyramiding of districts will become further complicated when the California Department of Water Resources constructs the Feather River project to bring water to Southern California. When this last step has been completed, the central basin will be obtaining its water from natural ground water, percolated flood waters, and, probably, reclaimed sewage. In addition, MWD water will be obtained from the Colorado River and from the California Department of Water Resources and will be distributed, in turn, directly to member agencies and indirectly for storage in the basins. If salt water conversion can be accomplished economically, a further complication may be added.

The success of the programs outlined above will depend on education of the public. Water producers will have to be organized to develop uniform thinking and plans. Unification has been very effectively accomplished in the western and central basins through association of all producers and interested parties. These associations, which include representatives of the water utilities, industries, chambers of commerce, and city councils of the area, meet once a month to review results of completed projects and proposals and to hear speakers on local and state water programs. The mu-

tual friendships and understanding developed through these meetings have provided a basis for the common understanding needed for implementing the programs. The associations also serve as the sounding boards for the board of directors of the municipal water districts. How the associations can aid in public education was demonstrated by a recent meeting held in Whittier and sponsored by five chambers of commerce. The meeting, together with the newspaper publicity that followed, was most helpful in acquainting the public with the basic facts and the need for the replenishment district.

Consolidation, or integration, of water utilities by means of overlying agencies, such as the western and central basin municipal water districts, offers many advantages to areas served by a multitude of utilities. The procedure provides an acceptable program where there is a multitude of interests and offsets the resistance of existing utilities and agencies to conform to a consolidation. It also obviates concern over the possibility that a consolidated utility may construct major works to achieve complete integration of the existing systems and thereby increase the cost of water service. Although the many devices used to assure the people of the central basin of a secure water supply appear complex, the administration and mechanics of the several programs are quite simple and are carried out with a minimum of cost and organization. The very simplicity of the organization and operation provides the flexibility which may be desirable for future consolidation at any level.

**Summary**

Water systems grow with the development of communities. Good planning must be based on principles tested by experience and proper consideration of variables, and the pattern of areawide planning of water development and distribution must be considered in the light of the existing needs and conditions. Where there is need for an imported supply, some form of agency is needed that has the resources to solve the problem on an areawide basis. Consolidation of existing utilities under one agency has been successfully used in many areas in California as the most efficacious means of satisfying all needs and, at the same time, of gaining universal acceptance. The establishment of overlying agencies to provide one or several means of satisfying all of the needs, so long as there are no appreciable overlaps or inefficiencies, can well be a permanent solution itself or a step toward an eventual solution.

The study of water supply and distribution problems has just recently reached the state level and is being pursued through the state water plan. The many large districts created in the past several years have been endorsed by the state and are part of the state plan for implementing its program without disturbing local autonomies and interests.

**Reference**

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## Discussion

**C. F. Wertz**

*Director, Dept. of Water & Sewers, Miami, Fla.*

Dade County, Fla., has a population of 900,000 people. Its area is more than 2,500 sq mi, but only 800–900 sq mi is usable at present for urban development or agriculture. The Miami Department of Water and Sewers supplies approximately 550,000 people in thirteen cities, towns, and villages and in a portion of the unincorporated county area.

Until the formation of the Metropolitan Dade County government in November 1957, no governmental agency was responsible for water supply in the unincorporated county areas, and, with the building boom after World War II, each developer had to provide his own water distribution system. If close enough, he connected to, and bought water from, the Miami system. Others put in their own water plants, which usually consisted of a well and a chlorinator.

A survey made in the latter half of 1958 disclosed that there were 46 privately owned water systems and 20 privately owned sewerage systems in Dade County. Of these, only ten are classed as major systems (750 or more connections), the largest being the Consumers Water Co., which supplies the cities of Coral Gables and South Miami and a large area in the county, for a total of 20,000 services. The total number of connections for the ten systems is 35,376. Eighteen minor community systems, each with fewer than 750 services, were designed for a total of 12,200 connections but have a present total of only 3,500.

Privately owned utility rates vary considerably, from a high of $2.50 monthly minimum for 4,000 gal to a low of $2.00 minimum for 6,000 gal or from 28½ cents to 62 cents for 1,000 gal. Miami rates are relatively low, however, the minimum being $1.25 per month for 4,500 gal (or 28 cents per 1,000 gal), and because Miami provides service in county areas at the same low rate, the metropolitan government has received many complaints regarding the higher rates. It would gladly turn the county problem over to the Miami department, but attorneys say that it is not possible without a refinancing of the Miami system. Miami has said that, if the metropolitan government can finance the installation of a distribution grid, the city can supply the water in a manner similar to the Metropolitan Water District of Southern California. The Miami department has two softening and filtration plants with a total capacity of 140 mgd. The capacity will be increased to 170 mgd by the end of 1960, and the site for a third plant, which will have a final capacity of 100 mgd, was recently acquired.

The government is currently thinking of setting up special tax districts to finance main extensions and has asked the Miami department to have its planning division prepare a master plan for the county areas. Thus far plans have been completed for taking over the first privately owned utility, the Key Biscayne Water Co.

# Progress of the California Water Plan

*Mercel J. Shelton*

*A paper presented on Jul. 14, 1959, at the Annual Conference, San Francisco, Calif., by Mercel J. Shelton, Chief Engr., Koebig & Koebig, Cons. Engrs., San Diego, Calif.*

THE California Water Plan (Fig. 1) has become a household word in California in recent years and has aroused considerable interest in many parts of the nation. At the end of World War II, the state legislature directed that a very thorough study be undertaken and that a report be submitted covering the total water resources, the total need for water for the ultimate development of the state, and ways to develop water to meet these requirements. The first unit of the California Water Plan, the Feather River Project, was adopted by the legislative in 1951.

After 1951, engineering studies and planning continued until, on Jul. 5, 1956, the California Department of Water Resources was created and began to function, bringing together a number of activities which had previously operated independently. These activities were in preparation for the tremendous task of constructing and operating the Feather River Project. The legislature, however, did not see fit to appropriate the necessary funds. A panel discussion was held in San Diego on Oct. 25, 1956, at the meeting of the California Section of AWWA. A full day's survey of the state's water problems and their proposed solution was presented (*1*).

In 1957 the regular session of the legislature again failed to appropriate funds. A special session in 1958, concurrent with the budget session, considered and debated the matter, but, with elections in the offing, no action was taken. Meanwhile, legislative interim committees held many meetings in various parts of the state to obtain the views of the citizens and public agencies regarding the problems of their area and to receive comments on the basic issues. Also, often at specific direction from the legislature, the California Department of Water Resources made special investigations of problems in various parts of the state and published reports for the information of all interested parties. As a part of its regular procedure, the department held public hearings on a number of these reports, while they were still in preliminary form, to obtain comments and information to aid in preparing the final report. All of these activities did much to acquaint the general public, governmental agencies, and legislators with the problems and thereby to develop a better understanding of the differing views.

## Action in 1959

The election in November 1958 placed a single political party in control in nearly all of the branches and offices of the state government for the first time in many years. The stage was set for action. Studies, planning

and reporting had been going on since 1946; reams of information were available; many reams more had been recorded during the hours of debate during the preceding 5 years; action was being demanded by nearly all segments of California. There appeared to be no question but that the 1959 legislature was destined to move forward with positive action. Senate Bill 1106, known as the "Burns Act" but cosponsored by a substantial majority of the senate, was introduced on Mar. 31. The act, officially called the California Water Resources Development Bond Act, differed from the past ap-

**Fig. 1. Feather River Development and Delta Diversions**

*Work on portions of the California water plan is already in progress. Passage of a 1.75 billion dollar bond issue will make California's water future secure.*

proach, which had been to adopt a constitutional amendment establishing a basis for the state to enter the field of water development and transmission. It is fair to say that for years a majority of both houses of the legislature have favored some kind of statewide water development. Nearly all sections of the state need it for one reason or another. Yet, efforts to freeze guarantees and reservations in the constitution, efforts of individual legislators to further projects for their own areas, and many other factors delayed adoption of a program.

The legislature adopted the California Water Plan as state policy. The plans call for construction of more than 375 dams and reservoirs, 5,000 mi of canals and pipelines, and will cost in excess of twelve billion dollars. The California Water Resources Development Fund was created by passage of AB 1062 by the legislature, thereby transferring about $190,000,000 from the Investment Fund (tideland oil funds).

**Bond Act**

Senate Bill 1106 passed the senate on May 29, 1959, and was approved by the assembly, without amendments, just 2 days before the end of the session. There had been many attempts to amend the bill, but, in view of strong statements that any amendment would kill all chances of passage at this session, they were all defeated. The bill does the following things:

1. Finances the water resources development system

2. Provides that state water facilities and projects authorized by the legislature be subject to provisions of the Central Valley Project Act

3. Defines the system and includes such additional facilities as may now or hereafter be authorized by the legislature as a part of the central valley project or the California Water Plan and including such other additional facilities as the department deems necessary and desirable to meet local needs and to augment the supplies of water in the Sacramento–San Joaquin Delta

4. Authorizes a 1.75 billion dollar bond issue for construction and creates a California Water Resources Development Fund

5. Provides that revenues from all projects are to be used for operation and maintenance of the state water resources development system, principal and interest on bonds, and for reimbursement of the California water fund, and that surplus revenues are appropriated to the department for the resources development system

6. Provides that the department contract for sale of water and power upon terms and conditions prescribed by the legislature while bonds are outstanding and revenues pledged to bond payment

7. Appropriates $130,000,000 of bond funds to be used for local development under the Grunsky Act, which provides for local project assistance

8. Requires that the California water fund (tideland revenues) and surplus revenues from all projects be used in lieu of bond proceeds for construction of state water facilities and provides that, to the extent the California water fund is so used, bonds may be sold and proceeds appropriated for other facilities of the resources development system, the nature of the facilities to be determined by the department as necessary to meet local needs and augment delta water supplies from multiple-purpose dams, reservoirs, aqueducts, and appurtenant works in the watersheds of the Sacra-

mento, Eel, Trinity, Van Duzen and Klamath rivers; authorizes the department to construct any and all facilities for which funds are appropriated to it; and provides that the legislature may, in any year, appropriate money in the California water fund for any lawful purpose

9. Establishes a committee, composed of the governor, treasurer, controller, director of finance, and director of water resources, to determine the time, need, and amount of bonds to be issued

10. Requires submission of the bond act to the people of California for ratification at the next general election in November 1960 and requires a majority vote.

### Current Construction

Actual construction preceded the 1959 legislative action; $25,190,000 was appropriated by the legislature in 1957 to start work on the relocation of facilities at the Oroville Reservoir site. Contracts were awarded for the construction of railroad tunnels totaling 13,200 ft in length. The highway relocation contract covered 13.3 mi and included 2.2 mi of railroad grading contracts. Contracts were also awarded for two railroad bridges, one over the North Fork of the Feather River and the other over the main stream of the Feather River. The total value of this contract work was nearly $21,000,000. Agreements were also reached by the state and various utility companies for relocating telephone lines, irrigation canals, and telegraph wires. All of the relocation work done thus far amounts to about 25 per cent of that necessary to divert facilities around Oroville Reservoir. It is programed for completion by the spring of 1960.

Design work has continued since the formation of the California Department of Water Resources, and the plans and specifications have been substantially completed for those features of the project which were expected to be placed under contract in the earliest phase of the construction program. A highlight in this connection was the controvery over two alternative types of construction for the Oroville Dam—arch and buttress and earthfill. The announcement was made by the department in December 1958, after receipt of the consulting board's recommendations, that Oroville Dam was to be constructed of rolled-earth and graded-gravel fill. Another major engineering study that took 3 years of exhaustive effort was a comprehensive study of alternative aqueduct systems to serve Southern California (Fig. 2).

### Description of Project

The Bond Act describes the project, in Section 12933 (d), as follows:

1. A multiple-purpose dam and reservoir on the Feather River in the vicinity of Oroville, Butte County, and dams and reservoirs upstream therefrom in Plumas County in the vicinity of Frenchman, Grizzly Valley, Abbey Bridge, Dixie Refuge, and Antelope Valley

2. An aqueduct system which will provide for the transportation of water from a point or points at or near the Sacramento–San Joaquin Delta to termini in the counties of Marin, Alameda, Santa Clara, Santa Barbara, Los Angeles and Riverside, and for delivery of water both at such termini and at canal-side points en route, for service in Solano, Napa, Sonoma, Marin, Alameda, Contra Costa, Santa Clara, San Benito, Santa Cruz, Fresno, Tulare, Kings, Kern, Los Angeles, Ventura, San Bernadino, Riverside, Orange, San Diego, San Luis Obispo, Monterey, and Santa Barbara counties

Said aqueduct system shall consist of intake and diversion works, conduits, tunnels, siphons, pipelines, dams, reservoirs, and pumping facilities, and shall be composed of a North Bay aqueduct extending to a terminal reservoir in Marin County; a South Bay aqueduct extending to terminal reservoirs in the Counties of Alameda and Santa Clara; a reservoir near Los Banos in Merced County; a Pacheco Pass Tunnel aqueduct from a reservoir near Los Banos in Merced County to a terminus in Pacheco Creek in Santa Clara County; a San Joaquin Valley–Southern California aqueduct extending to termini in the vicinity of Newhall, Los Angeles County, and Perris, Riverside County, and having a capacity of not less than 2,500 cfs at all points north of the northerly boundary of the County of Los Angeles in the Tehachapi Mountains in the vicinity of Quail Lake and a capacity of not less than 10,000 cfs at all points north of the initial offstream storage reservoir; a coastal aqueduct beginning on the San Joaquin Valley–Southern California aqueduct in the vicinity of Avenal, Kings County, and extending to a terminal at the Santa Maria River

3. Master levees, control structures, channel improvements, and appurtenant facilities in the Sacramento–San Joaquin Delta for water conservation, water supply in the delta, transfer of water across the delta, flood and salinity control, and related functions

4. Facilities for removal of drainage water from the San Joaquin Valley.

5. Facilities for the generation and transmission of electrical energy.

6. Provision for water development facilities for local areas as provided in Chapter 5 (commencing at Section 12880) of Part 6 of Division 6 of the Water Code as the same may now or hereafter be amended

7. Including, for the foregoing (1 through 5), the relocation of utilities and highways and acquisition of all lands, rights of way, easements, machinery, equipment, apparatus, and all appurtenances necessary or convenient therefor.

The project incorporates what is commonly referred to as the "delta pool concept." This consists of pooling of the surplus waters of northern California, with the delta as the focal point for collection and diversion, in order to assure a firm water supply to the areas of deficiency west and south of the delta and, at the same time, provide for the water needs of the areas of origin. "Surplus waters" are defined as those in excess of the amounts needed for beneficial purposes in the areas of origin; the needs of the areas of origin will gradually increase with time. It is obvious that the delta pool concept implies both complete operational integration of all conservation facilities supplying water to the common point of diversion and financial integration of successive projects constructed by the state.

The bond issue is estimated to be sufficient to finance the project in its entirety. Revenues from the sale, delivery, or use of water or power and all other income or revenues from the capital system are to be deposited in a special account in the California Water Resources Development Fund and are to be accounted for and used annually for the following purposes and in the following order:

1. Payment of reasonable costs of annual maintenance and operation of the system and replacement of any parts of it

2. Annual payment of the principal of and interest on the bonds

3. Transfer to the California water fund as reimbursement for funds utilized from the latter for construction of the system

4. Any surplus revenues in each year not required for the purpose specified above are to be deposited in a special

account in the California Water Resources Development Fund. They are appropriated for the use of, and are to be available for expenditure by, the department for acquisition and construction of the system. All such revenues are to constitute a trust fund and are pledged for the uses set forth above.

**Department Program**

Before the legislature passed the bond act, it had approved the budget, which includes funds totaling $83,000,000, appropriated from the California water fund (tideland revenues) to perform certain work specifically directed by the legislature. It was indicated that immediate action was to be taken. The calling of bids is to be opened in August or September 1959 for:

1. Construction of the West Branch Bridge, which will carry both highway and railroad traffic as a part of the relocation of transportation facilities around the Oroville Dam and Reservoir

2. Drilling of two railroad tunnels and additional grading of the railroad right of way (Items 1 and 2 will complete all highway and railroad relocation work. Bid call for the tunnel work was released on Jul. 3.)

3. Construction of Frenchman Dam in the Upper Feather River Basin

4. Construction of the first unit of the South Bay Aqueduct

5. Finishing the acquisition of the right of way for the Oroville Reservoir

6. Continuing and expediting design of Oroville Dam and the aqueduct system

7. Immediately obtaining necessary lands for terminal reservoirs in Southern California (These are Castaic, Devils Canyon, and Perris; acquisition is to include necessary lands for recreational features at each reservoir.).

In addition to the construction and acquisition program, the department is to:

1. Start negotiations with local agencies for both water and power contracts (The first such negotiation meeting was scheduled with the Metropolitan Water District of Southern California on Jul. 7, 1959.)

2. Immediately proceed to set up rules and regulations covering loans and grants under the Davis-Grunsky Act passed during the 1959 session amending the Grunsky Act of the 1958 session (To implement this program, $15,000,000 is appropriated in the current budget.)

3. Start detail studies as to the proper means of furnishing water in the delta, protecting the area from floods, and protecting water quality

4. Continue planning studies.

**Further Action**

As momentous as was the passage of the bond act, there remains an even greater hurdle—a favorable vote at the polls in November 1960. The task is great and requires a public information program such as the state has never seen. Why is this necessary? It is true that nearly all areas of the state will benefit from the ultimate development of the California Water Plan. Many areas will receive a direct benefit in the form of flood control, water conservation and deliveries, recreation, power, and other possible uses; other areas may receive only indirect benefits—particularly areas that have developed their water supplies through local initiative. Many such areas have reached out hundreds of miles for their supplies, and some still have untapped sources awaiting development.

Engineers and others who have made a thorough study of the problem

know that the construction program must move forward at a rapid pace if the state is to continue with an orderly economic development. The responsibility rests with these individuals and organizations to insure that the rest of the state's population is acquainted with the facts of the situation that they may cast an intelligent vote. This is difficult if for no other reason than that people are tax conscious and resist any program which they believe will increase the taxes. The members of the California Section of AWWA, who are familiar with the details, have a responsibility to assist in every way possible in bringing about public understanding.

## Conclusion

The people of California are fortunate to have had the leadership in state government and the willingness on the part of many groups throughout the state to draft and adopt such legislation as is represented in SB 1106. Even those who had a part in the action realize that the legislation is not perfect and that, after careful study in the next few months, it may be necessary to submif further legislation. There may be technical omissions, or it may be necessary to resolve some controversial points that were bypassed in order to avoid further delay in adopting the basic legislation. Any new legislation could be submitted at a special session, which would be called in the spring of 1960. Items of such legislation could include terms of contracts and repayment, acreage limitations, the public power preference rule, and other equally important points.

Construction has been authorized and will use funds from the California water fund. There are sufficient funds available from this source to continue the construction for about 2 years. Passage of the bond act by the people of the state will assure continuation of the construction program.

The California Department of Water Resources is faced with a task never before faced by a governent agency. It has long been a data collection and planning agency *; within months, it is to take over construction of the largest water development project ever conceived and to assume the role of a utility to deliver water when and where it is needed.

California has made great strides toward using its natural resources and inherent capacity for accomplishment to insure adequate development and use of its water supplies. Some of the greatest challenges to California's leadership will be in the future. The challenge of water development can be met, but only with the thorough understanding and support of the people.

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# Future Water Requirements in Oklahoma

——George W. Reid, Guy B. Treat, and F. J. Wilson——

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MOST studies to determine future water requirements have been based on past experience, and, in general, three basic use, or consumption, classifications have been used—municipal, direct industrial, and agricultural. Traditionally, consumption has been expressed on a unit basis—that is, gallons per capita, gallons per unit of product, or gallons per irrigated acre. All uses are in some way related to population, however, and, separately or collectively, may be so expressed. The total requirement for a specific date is the product of the unit per capita consumption and the population.

In this study, the three traditional classifications are used and correlated with population. Conventional techniques of population extension were not considered adequate for this study. Although they are useful as reference points, they were not utilized in the determination of future unit water consumption.

## Population

Population estimates for Oklahoma were determined by use of projections of the present population of the United States by both incremental and logistic methods (*1*). In the approach used, unlike more conventional methods, it was not assumed that the state's present percentage share in the national population would remain the same in coming years. Rather, it was assumed that no migration in or out of the country would take place during the period of projection and that some of the already saturated areas would be unlikely to undergo any large increases in population—that is, that migration would be likely to take place from densely populated areas to those more sparsely populated areas that are capable of urban development. It was also assumed that there would be a major increase in Oklahoma's available water supply, and that, with a sufficient water supply, three factors—the urban growth rate, urbanization, and population density—could be expected to follow the same general pattern they have followed in other well watered areas. Estimates of Oklahoma's share in projected national population increases were therefore weighted by these three factors. An independent population synthesis was developed by the curvilinear method based on actual population densities of well watered industrialized areas. In all, ten different values were calculated. On the basis of the method described, projections of Oklahoma's population were determined as 2,890,000 for 1975, 4,500,000 for 2000, and 5,380,000 for 2025.

## Municipal Requirements

In municipal use are included domestic, industrial, public, and commer-

cial uses, as well as distribution system losses. Small, residential towns have few industrial and commercial requirements. Newer cities have better distribution facilities and, therefore, fewer losses. Normally, one human being uses 25–30 gpd for domestic and sanitary purposes. Added to these are the amounts used for lawn watering, air conditioners, automatic washers, and other appliances. Thus, residential towns may use 50–80 gpcd. Industrial areas use considerably more water per capita. Because the degree of industrialization usually increases with increased population, unit per capita consumption can be expected to increase. It can also be expected to increase by virtue of improvements in the standard of living—that is, increasing numbers of air conditioners, automatic washers, and other water-using appliances. The influence of these parameters has been confirmed by experience; their usefulness in projections of future water use is dependent upon whether a workable technique can be developed that will take them into account.

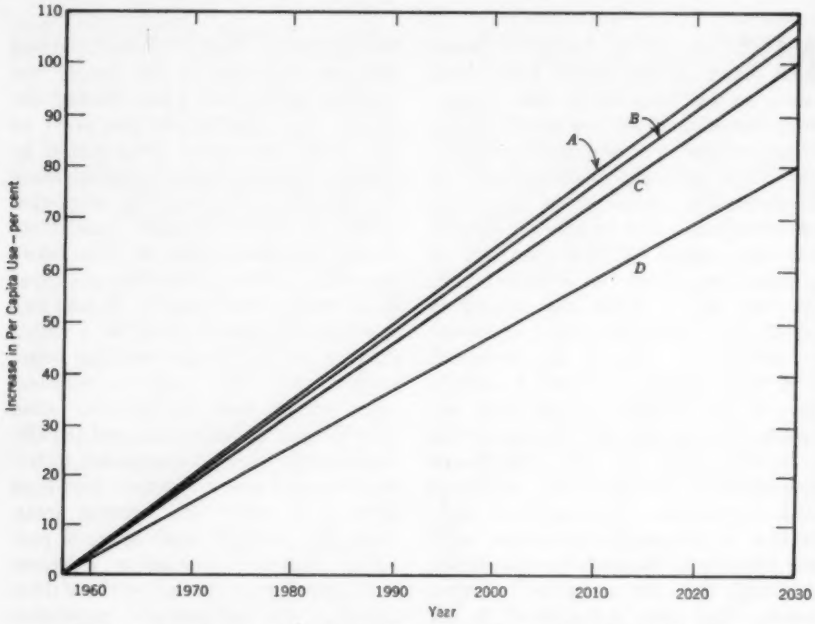


**Fig. 1. Increases in Per Capita Use According to Population Density**

*Curves* A, B, *and* D *represent increases in use for population ranges of 25,000, 10,000, and 500,000 respectively; Curve* C *represents the average increase.*

To use the basic assumption of the population studies—that, with an adequate water supply, Oklahoma could grow just as other well watered areas have grown and are growing—it was necessary to correlate unit consumption estimates for Oklahoma with those

of well watered areas and, at the same time, provide for the increases in demand that would result from a general improvement in the standard of living.

Per capita consumption figures were first determined for the years 1975, 2000, and 2025; these were 148, 185, and 235 gpcd, respectively. In 1950, consumption was 81 gpcd in Oklahoma, and in 1955 it was 103 gpcd. The average for the nation was 137–142 gpcd in 1950 and 143–154 gpcd in 1955, as shown in Table 1 (*2*). A study of public water supplies in 1955 indicated that well watered areas used 1.8 times as much water per capita as was used in Oklahoma (*3, 4*).

Various estimates put United States consumption at 153, 200, and 280 gpcd for 1975. The projected unit consumption for Oklahoma placed the state's 1975 consumption near the lowest of the national estimates, or at 148 gpcd. The state's estimated consumption for the year 2000 was close to the present consumption in well watered areas, or at 185 gpcd. By traditional methods alone, well watered areas would be expected to use 228 gpcd in 2000. A consumption of 235 gpcd would be quite reasonable for a well watered, industrialized area in 2025. The national consumption would be 253 gpcd by histogramatic projection. At these values, the incremental increase would be 2 gpcd per year until 1975 and 1.75 gpcd per year thereafter. This is shown graphically in Fig. 1. The actual increase in the national consumption has been nearly 1 gpcd per year; during 1930–55 it increased from 120 to 143 gpcd, or $\frac{23}{25}$ gpcd per year. Total municipal requirements were computed by multiplication of per capita consumption projections by the corresponding population projections. The figures for 1975, 2000, and 2025 were, respectively, 161, 308, and 609 bil gal per year.

It is important to bear in mind that the greater portion of the increase in total consumption—and, hence, per capita consumption results from industrial development and that it is expected that industrial uses will account for a greater percentage of the unit

TABLE 1

*Per Capita Consumption in the United States and Oklahoma, 1900–75*

| Year | Consumption—*gpcd* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | United States | | | | | Oklahoma | | |
| | Industrial | Municipal | Irrigation | Rural | Total | Industrial | Municipal | Total |
| 1900 | | | | | 600 | | | |
| 1930 | | | | | | | 71 | 62 |
| 1950 | | 142 | | | 1,100 | | 81 | 108 |
| | | 137 | | | | | | |
| 1955 | 730 | 154 | 80 | 100 | 1,700 | 20 | 103 | 123 |
| | | 143 | | | | | | |
| 1975 | | 200 | | 125 | 2,180 | | | |
| | | 280 | | | | | | |
| | | 153 | | | 1,800 | | | |

consumption in Oklahoma than they will in most of the nation. In other words, the estimates for Oklahoma consumption may be low, because they were based on the assumption that industrial development would require little or no direct industrial water. The national requirement for industrial water was 6.85 times the total municipal requirement in 1955; in 1975 it is expected to be 6.67 times the total municipal requirement. In this study, the direct industrial requirement was predicted to be less than the municipal requirement in 1975 and 1.1 times the municipal requirement in 2025. In the year 2000, the direct industrial requirement was predicted to be 1.08 times the municipal requirement.

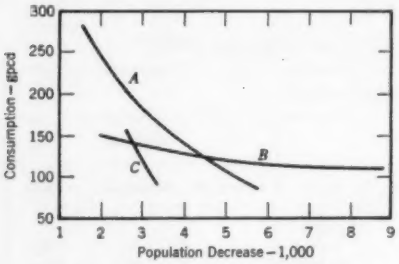


**Fig. 2. Decreases in Per Capita Consumption With Decreases in Population Density**

*Curves* A, B, *and* C *represent population ranges of 10,000, 500,000, and 25,000 respectively.*

Consumption estimates for individual counties and cities may be arrived at by the same method. Individual unit consumption figures are determined by comparisons with well watered cities according to population density and the general trend toward a better standard of living. The cities selected for this study included Atlanta, Ga.; Dallas, Tex.; Leavenworth, Kan.; Indianapolis, New Castle, and Columbus, Ind.; and San Diego, Pomona, Burbank, Santa Barbara, Alameda, Vallejo, Burlingame, and Eureka, Calif. A table was prepared from data on three population groups, 500,000, 25,000, and 10,000; unit consumption was plotted against population density (Fig. 2). The appropriate unit consumption figure may be selected for any projected population. The effects on water consumption of general improvements in the standard of living are represented by a linear plot based on historical trends in well watered communities (Fig. 3). Good judgment is necessary to derive any final figures. The figures set forth in this study are believed to be conservative. A general set of curves for requirements in Oklahoma cities is given in Fig. 4.

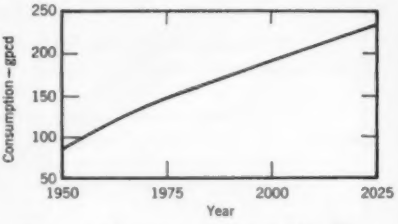


**Fig. 3. Increases in Per Capita Consumption, Municipal Use**

*Comparison of the curve above with the municipal-use curve in Fig. 5 reveals that, although per capita consumption is likely to triple in the 75-year period between 1950 and 2025, actual consumption is expected nearly to quadruple.*

### Direct Industrial Requirements

Industry uses water for power generation, cooling, processing, and sanitation. In 1955 approximately 120 bgd was used by industry, of which 90 per cent was for power, and the rest

was for other purposes. The estimates for 1975 bring the national total industrial consumption to 290 bgd. In 1955, industrial consumption accounted for 48 per cent of total water used, with agricultural and municipal uses accounting for 45 and 9 per cent respectively. By 1975, industrial consumption is expected to account for 60 per cent, with agricultural and municipal uses accounting for 31 and 9 per cent respectively. During 1950–56 there was a 43 per cent increase in the direct industrial requirement. Oklahoma's industrial use in 1955 was 16.7 bil gal, or 14 per cent of the total use.

Of the nation's total industrial water use, $\frac{2}{3}$–$\frac{3}{4}$ is used in the manufacturing belt; three states, New York, Pennsylvania and Ohio, use 40 per cent. Studies have indicated, for example, that Ohio uses ten times as much water as Arkansas (the nearest comparable consumer on which data are available). The two states have an unsatisfied requirement for an amount equal to their present combined use, or a 50 per cent increase for Ohio and a 450 per cent increase for Arkansas. The total municipal consumption in the United States was 17 bgd in 1955, as compared with 15 bgd for process water. In the past 25 years, municipal requirements have increased only 50 per cent, whereas industrial use has increased 170 per cent.

In projections of industrial consumption, the possibility of conservation of water in new industrial development was taken into consideration. There is a real need for increased conservation in Oklahoma, particularly in the period from now until 1975. It is hoped that industrial development will proceed without creating wasteful uses, and that reuse will be practiced wherever feasible. Reuse could conceivably increase effective supplies threefold, as have other conservation practices. More effective utilization of water has made possible a reduction in the amount needed to produce 1 kwhr of electric power from 150 gal to 2 gal; likewise, whereas it once took 50,000 gal to produce 1 ton of steel, it now takes only 1,400 gal; although it once took 14 gal to produce 1 lb of carbon black it now takes only 0.25 gal.

Industrial water requirements were computed with the assumption that

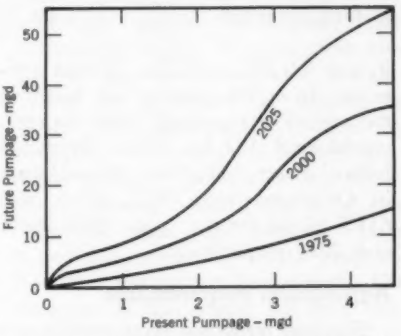


**Fig. 4. Comparison of Present and Future Pumpage in Oklahoma**

*As can be seen, the greatest increase in pumpage is not expected to take place until after 1975.*

industrial use would gradually approach a basic process requirement with only a modest cooling requirement. It was assumed that conservation and reuse would be practiced by many of the new Oklahoma industries, and that no industry would use an excessive amount of water. Unit requirements for selected industries are given in Table 2 (*5–8*).

In 1955, the national ratio of process water consumption to municipal use was 15:17 or 0.89; in Oklahoma

TABLE 2

*Average Daily Consumption in Various Industries, 1954*

| Industry | Water Consumed per Worker *gpd* |
|---|---|
| Paper manufacturing | 20,600 |
| Petro-chemical production | 5,000 |
| Petroleum refining | 5,000 |
| Metal smelting and fabrication | 2,500 |
| Chemicals production | 2,000 |
| Glass production | 1,900 |
| Cement production | 1,500 |
| Food processing | 630 |
| Transportation equipment | 400 |
| Machinery (nonelectrical) | 400 |
| Printing and publishing | 260 |
| Clothing production | 60 |

it was 52:233, or 0.22. It was estimated from the criteria set forth in the preceding paragraph, that the ratio would read 1:3 by 2025. Predicted future direct industrial requirements in Oklahoma were 94.5, 423.6, and 651.7 bil gal for the years 1975, 2000, and 2025 respectively.

## Agricultural Requirements

National irrigation requirements are increasing, although irrigation will probably lose considerably to industry, percentagewise, as a water user in the next few decades.

Irrigation is relatively new to Oklahoma. Approximately 150,000 acres are under irrigation at present. That the value of irrigation is largely determined by whether it can produce significant increases in crop yield is obvious. Some crops respond better to irrigation than do others; only if crops can be reasonably increased should irrigation be considered. Increases in the yield of cotton lint from 150 lb/acre to 600 lb/acre have been produced through the application of 13 in. of water at the right time.

Unsuitability of the land, flooding hazards, and lack of adequate drainage limit the applicability of irrigation, but the greatest single limiting factor is cost. There are approximately 2,012,000 acres of physically irrigable land in Oklahoma. What portion of this land will be economically irrigable in 25–50 years is difficult to predict. Advances in technology may bring the costs of irrigation within reach of farmers to whom they are now prohibitive.

At present water for irrigation of grain should cost $4–6 per acre-foot, including the cost of system maintenance. In Oklahoma, irrigation has never been extensively used for truck crops, but high-value crops should be studied to determine the chance of a better return on irrigation costs. It is possible that as much as $700 might be brought per acre, whereas cotton

TABLE 3

*Water Consumption in the United States, 1900–1975*

| Year | Water Required—*bgd* | | | | |
|---|---|---|---|---|---|
| | Industrial | Municipal | Irrigation | Rural | Total |
| 1900 | 10 | 3 | | | 40 |
| 1940 | 51 | 10 | 71 | | 135 |
| 1950 | 84 | 14 | 100 | | 203 |
| 1955 | 120 | 17 | 120 | 5.4 | 262 |
| 1975 | 246 | 30 | 170 | 7.5 | 453 |

TABLE 4

*Water Consumption in Oklahoma, 1930–55*

| Year | Consumption—*mgd* | | | |
|---|---|---|---|---|
| | Industrial | Municipal | Irrigation | Total |
| 1930 | 25 | 170 | 1 | 197 |
| 1940 | 22 | 133 | 1 | 149 |
| 1950 | 39 | 192 | 3 | 241 |
| 1955 | 52 | 233 | 150 | 481 |

brings only $150. A crop moisture requirement of 2.3 ft/acre is considered an acceptable average.

To determine irrigation use for future years, it was assumed that 660,000 acres would ultimately be irrigated in Oklahoma. Multiplication by a moisture requirement of 2.3 ft/acre gives 1,272,000 acre-ft (414 bil gal) for the year 2025. The years 2000 and 1975 would have irrigation requirements of 310 and 130 bil gal respectively. Acreages used in the derivation of these figures were based on accessible terrace and alluvial lands that could be expected to be irrigated locally.

## Total Requirements

The United States withdraws approximately 25 per cent of its available water and consumes approximately 5 per cent, or 262.04 bgd, of which 41.24 bgd is ground water. The nation's total unit consumption is 1,200 gpcd. In 1955, Oklahoma used 0.481 bgd (Tables 3 and 4) (*10–18*). The state's total water consumption has been doubling every 25 years, or increasing at the rate of 3–4 gpcd/yr. Total future requirements were projected by combining projections of use in three categories, municipal, agricultural, and direct industrial requirements (Table 5).

Both industrial and agricultural supplies are usually immediately used whereas municipal supplies must usually undergo processing and storage. Water so processed is subject to losses. It is anticipated that each municipality will provide 2–3 days' raw-water storage. Experience has shown that it usually is necessary to provide 3 gal for each 2 gal pumped. It is hoped that processing losses, evaporation, and seepage can be reduced. For purposes of this study, the total municipal requirement was computed by multiplying the estimate for pumped water by a factor of 1.45, rather than the current factor of 1.5.

The total water requirements for 1975, 2000, and 2025 were estimated

TABLE 5

*Oklahoma Water Requirements, 1950–2025*

| Year | Population *1,000,000* | Unit Consumption *gpcd* | Water Required—*bil gal* | | | | |
|---|---|---|---|---|---|---|---|
| | | | Municipal | Irrigation | Industrial | Adjusted Municipal * | Total |
| 1950 | 2.2 | 86 | 68.4 | 2.0 | 31.9 | 99.2 | 133.1 |
| 1955 | 2.3 | 103 | 84.7 | 97.8 | 33.2 | 122.8 | 253.8 |
| 1975 | 2.9 | 148 | 159.7 | 130.3 | 94.5 | 231.5 | 456.4 |
| 2000 | 4.5 | 185 | 307.9 | 304.6 | 423.6 | 446.5 | 1,179.7 |
| 2025 | 5.4 | 235 | 469.2 | 414.5 | 651.7 | 680.4 | 1,746.6 |

* Municipal requirement multiplied by a factor of 1.45; the amount of water necessary to pump a given demand is estimated to be 1.45 times that demand.

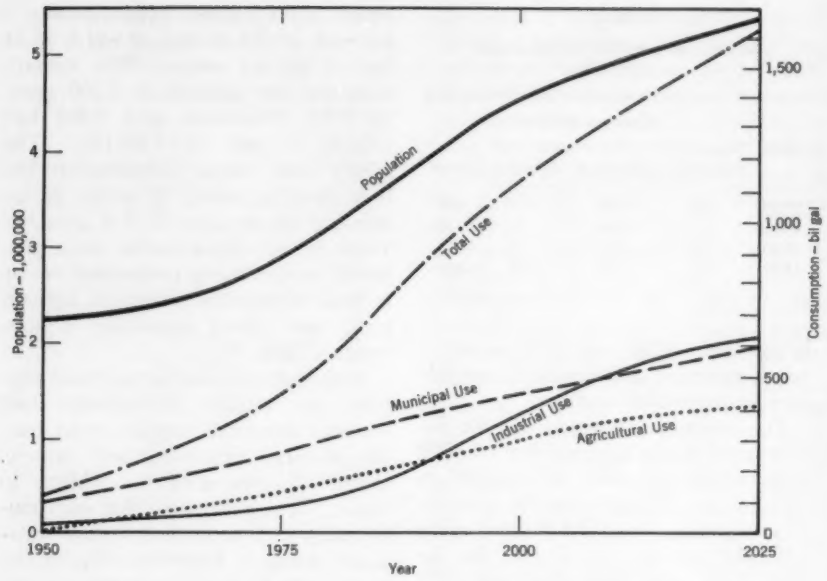


**Fig. 5. Future Water Use in Oklahoma and Population Increases**

*The population curve refers to the left-hand scale; curves for use projections refer to the right-hand scale.*

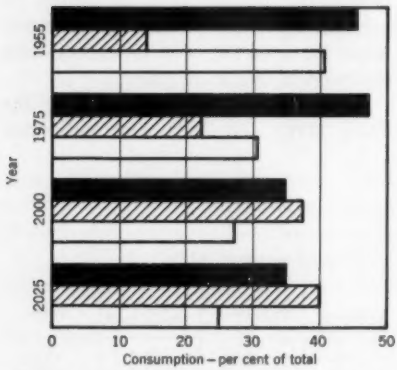


**Fig. 6. Use Distribution in Oklahoma in 25-Year Increments**

*The black, cross-hatched, and open bars represent municipal, industrial, and agricultural use, respectively.*

to be 456, 1,196, and 1,698 bil gal, respectively. These data are shown graphically in Fig. 5. A study of the distribution of use in the three use categories (Fig. 6) reveals a percentage decline in municipal use from 45.5 per cent in 1955 to 34 per cent in 2025; during the same period agricultural use should be reduced from 40.5 per cent to 21.5 per cent. Direct industrial use, however, should increase from 14 per cent to 47.5 per cent.

## Conclusion

Reasonable projections of total net water requirements in the state of Oklahoma have been presented for the years 1975, 2000, and 2025. The figures are based on a projection method

that was largely logistic, being based on the assumption that, if Oklahoma gains a plentiful water supply, industrialization and increased population should result, and should follow the same basic pattern as they have followed in other well watered areas. In deriving the figures set forth in this article, the authors made constant reference to the figures advanced by other groups, and trends in various well watered areas were used as guideposts.

The authors realize the limitations inherent in any technique that purports, either on the basis of statistical data alone or by use of logical parameters in combination with statistics, to project many years into the future. Suffice it to say, however, that the authors consider the estimates, if anything, conservative.

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# Long-Range Weather Forecasting as a Water Supply Tool

*Irving P. Krick*

*A paper presented on Jul. 14, 1959, at the Annual Conference, San Francisco, Calif., by Irving P. Krick, Pres., Irving P. Krick Assocs., Denver, Colo.*

IN this age of challenges, full and effective development of water resources is one of the greatest. The rise in water consumption caused by population increases and accelerated industrial growth and development requires farsighted planning to meet the water demand of the future.

## Streamflow Control and Use

Of the water used in the United States, approximately 80 per cent comes from surface sources and only about 20 per cent comes from underground, because surface water (streams and lakes) is more plentiful and accessible than underground water.

The type streamflow control varies with the intended use for the water, but a reliable streamflow forecast is a major tool in all water supply planning. Municipal water supply reservoirs, for example, smooth out the erratic flow and are able to meet a more uniform demand by holding back enough water during spring floods to allow for high demand or small flows during the dry season. If extremely small flows are forecast for the dry season and the reservoirs are not filled, municipalities may be in a position to limit water consumption to a certain extent in advance in order not to deplete the reservoir storage.

### *Flood Control*

Flood control requires an empty reservoir to hold back excess water and keep the river within its banks downstream from the dam. After the flood flow subsides, the reservoir is drawn down quickly to empty it for the next flood. In 1958, record floods on many streams put flood control systems to some of the severest tests in history; damage in California alone was estimated at approximately $50,000,000.00.

### *Transportation*

Economically developed navigable water is frequently the cheapest mode of transportation for bulk raw materials and heavy commodities basic to agricultural and industrial production. Sound national water policy requires that navigable water resources be developed and used to the fullest economical extent. Navigation control regulates variable streamflow to keep downstream water deep enough for shipping during the dry season.

### *Power*

During the past quarter-century, the federal government embarked upon an accelerated program of development of the principal rivers of the nation. The program has included construction of

many large dams where hydroelectric power installations are producing large quantities of electric energy. Low-cost energy holds the promise of new and expanded industrial uses. The past 60 years have seen the country's electric-power supplies increase from a few thousand kilowatts to 67,000,000 kw. Today, water power provides about 17,500,000 of utility capacity. The development of hydroelectric power is of major importance in the Pacific Northwest—not only because of the area's great economic potential, but also because it has scant quantities of coal and no known oil or natural-gas reserves. Therefore, industrial development in that area is tied closely to the hydroelectric-power resources of the Columbia River System. Experts have estimated that the whole Columbia River System might possibly support an installation of 50,000,000 kw. Two-thirds of that amount could be made available with a headwater storage program of approximately 30,000,000 acre-ft. The Federal Power Commission estimated that 34,000,000 kw would be economically feasible. Hydroelectric-power generation needs water at a high elevation, and a power reservoir should therefore always be kept as full as possible. During high flows, plants operate on a base load and produce as much energy as possible. Low river flows are stored during the day and weekends for release through water turbines during the system's short daily peak loads. In an emergency, however, a reservoir could be drawn down.

*Irrigation*

Another of the numerous uses of streamflow is irrigation, which accounts for approximately 100 bgd. The irrigation economy, which has yielded a wealth of fruit, grains, vegetables, range land, and pasture and has greatly improved the farm output, depends mostly on streamflow.

The amount of streamflow also determines to a great extent the regulation of releases of water in order to make fullest use of a stream's potential self-purification capacity.

**Forecasting Techniques**

In the foregoing the importance of reliable streamflow forecasts for proper water supply planning has been stressed. The large variations in monthly and seasonal distribution of the annual runoff in most river basins pose a major problem, especially in the operation of hydroelectric-power systems.

In projecting firm power capabilities for a coming year, most power producers use rule curves based on a low water year and on the median water year. Some improvement in this procedure has recently been achieved by the use of a combination of historical streamflow correlations and antecedent conditions for the determination of an initial point on the "dependable" streamflow projection at the time of each forecast (*1*). The curve for the critical water year is then used to project from that point. Unfortunately, such a procedure still tends to minimize the total inflow forecast at the outset of each water year and to fix the shape of the streamflow curve from month to month. In the Columbia River Basin, for example, it has invariably led to a forecast of sharp streamflow reductions in winter to conform with the characteristics of the

critical year (1936–37). The low flows during the winter period in that year were caused by a weather sequence of rare and infrequent occurrence, however. Thus estimates of firm power capabilities, if based upon the unusual characteristics of the 1937 winter, greatly minimize the flexibility of power system operation in the area during most years. As the season progresses, streamflow estimates are issued monthly by various agencies, based upon snow survey information and data for the normal precipitation for the balance of the season. Many types of correlations have been developed in order to produce probabilities of streamflow within various ranges, but they all suffer from the same limitation—an inadequate knowledge of the actual sequence of precipitation and temperatures that will be responsible for streamflow during the course of a given water year.

This article outlines procedures for forecasting the sequence of precipitation and temperature during a water year and for conversion to "dependable" streamflows. It is possible, through the use of this method, to produce a firm estimate of dependable seasonal inflows, either for a single river basin or a complex of river basins, such as the Columbia, without any reference to the critical water year. The method permits the discernment of low and high water years unrecorded in the historical data.

TABLE 1

*Total Streamflow Estimates for Pacific Northwest Water Year, October 1957–September 1958*

| Datum | Lewis River | | Grand Coulee Dam | |
|---|---|---|---|---|
| | Streamflow *acre-ft* | Per Cent of Normal Flow | Streamflow *acre-ft* | Per Cent of Normal Flow |
| Author's forecast | 3,355,700* | 100 | 76,744,000 | 98 |
| Actual | 3,253,509 | 97 | 75,230,100 | 96 |
| Average for 15 years | 3,346,000 | | 78,280,000 | |
| Monthly US Weather Bureau forecasts | | | | |
| Jan. | 3,370,000 | 101 | 74,400,000 | 95 |
| Feb. | 3,490,000 | 104 | 75,600,000 | 97 |
| Mar. | 3,610,000 | 108 | 77,100,000 | 99 |
| Apr. | 3,500,000 | 105 | 73,700,000 | 94 |
| May | 3,700,000 | 111 | 76,200,000 | 97 |

* The author's original forecast, released in September 1957, proved reliable. The monthly US Weather Bureau forecasts were continually revised (and raised) on the basis of actual reports of precipitation and streamflow.

A list of various 1957–58 water year forecasts, prepared for the Lewis River at Merwin Lake in Washington and for the total inflow at Grand Coulee in Washington, is given in Table 1.

The importance of streamflow estimates is greatest during the fall months. Storage may safely be drawn down at that time in a year such as 1957–58, when the characteristics of the streamflow projections for the winter months depart radically from 1936–37. This is verified by the monthly flows at Grand Coulee and

Merwin Lake (Table 2) where a decreasing flow in relation to the usual median flow trends projected for November was followed by a sharp upturn by February. The actual flows confirmed this pattern. The forecast scheme mentioned above (*1*) utilizing antecedent conditions as a starting point for a streamflow project and the 1936–37 characteristics for succeeding months, would not indicate on December 1 the upturn in January and February, but a decided decrease in flows during those months.

**Benefits of Method**

The continued refinement and extension of the method of streamflow forecasting to be described in this article could provide for a firm estimate of dependable flows without the use of statistical relationships that have no basis in physical fact. Important benefits not now obtainable would be afforded power, flood control, irrigation, navigation, and other conservation groups.

*Power*

With more dependable streamflow predictions, greater amounts of secondary energy could be sold by the federal government and nonfederal utilities. The expense of steam generation by private utilities would be minimized and cyclical storage, such as in the Hungry Horse Project, Montana, could be drawn upon in greater amounts, with no risk of shortages, to meet prior commitments. Storage water that is held in abeyance under critical water conditions could be released ahead and be fully utilized, instead of wasted. With advance knowledge of available supply, industry could schedule production and avoid abrupt curtailments.

*Flood Control*

Water spilled from a reservoir to provide space for flood control could, if streamflow could be accurately predicted, be conserved to generate power or to meet other conservation needs later. Flood plains could be profitably farmed and harvested during forecast periods of low runoff. Protective measures could be taken much in advance during forecast periods of high floods.

TABLE 2

*Actual and Forecasted Streamflow Variations, Dec. 1957–Apr. 1958*

| Watershed and Month | Direction of Change | | | Relationship of Actual Streamflow and Forecast to Median | |
|---|---|---|---|---|---|
| | Actual | Forecast | Median | Forecast | Actual (Per Cent of Median) |
| Lewis River | | | | | |
| Dec. | up | up | up | near | 130 |
| Jan | —* | —* | —* | above | 130 |
| Feb. | up | up | down | above | 184 |
| Mar. | down | down | down | above | 74 |
| Apr. | up | up | up | above | 126 |
| Grand Coulee | | | | | |
| Dec. | down | down | down | near | 91 |
| Jan. | —† | —† | down | above | 101 |
| Feb. | up | up | —† | above | 142 |
| Mar. | —† | —† | up | near | 112 |
| Apr. | up | up | up | near | 98 |

* Little or no change (± 150 cfs/mo).
† Little or no change (± 1,000 cfs/mo).

*Irrigation*

Prior knowledge of runoff would modify the irrigated and nonirrigated cropping practice. Releases could be made to supplement water supply to lands now inadequately irrigated. Water stored for irrigation could safely be released in advance if additional flood control space were needed.

**Evolution of Method**

The streamflow forecasting procedures described herein are an adapta-

tion of the methods of ultralong-range weather forecasting, evolved during the last 25 years by the staff of the American Institute of Aerological Research. The work began at the California Institute of Technology, where the author and his associates directed

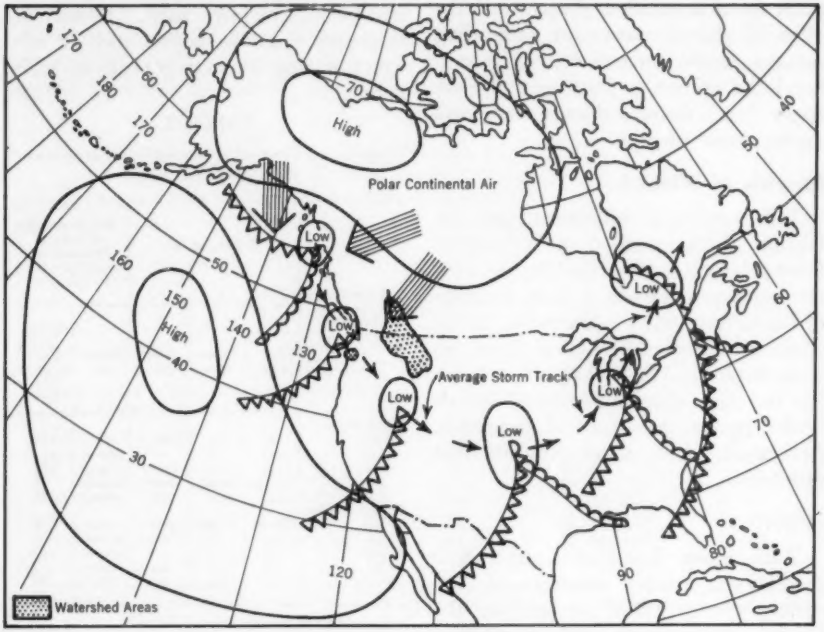


**Fig. 1. North American Weather Type *A***

*This weather type is characterized by two high-pressure areas shown. A 6-day storm progression across the continent is shown by successive daily positions of the low-pressure areas their attendant fronts. Type* A *weather brings extremely cold weather to the Lewis and Upper Columbia watersheds and was responsible for the critical flows of 1936–37.*

the activities of the Department of Meteorology from 1933 to 1948 (*2, 3*).

The method entails the study and analysis of systematic behavior features of globe-circling atmospheric pressure waves. From an examination of historical weather data in the form of Northern Hemispheric daily surface weather charts on which the barometric pressure patterns are drawn, certain conclusions may be drawn. It has been found possible to categorize various sequential pressure patterns that represent fundamentally stable flow patterns in the atmosphere. These patterns are called "weather types." The validity of the classification is a confirmation of the ordered nature of atmospheric behavior and the fact that the wind systems have certain pre-

ferred positions in relation to the geographic features of the earth's surface and that terrestrial and extraterrestrial forces pulse the atmosphere. The catalog of weather types, prepared from an examination of the historical archive of daily weather charts for the Northern Hemisphere, is a useful tool in forecasting because it provides a means of making full use of historical data in preparing future weather estimates. This is done by matching the projected weather type sequences with similar fragments of the historical record, thus permitting a synthesis of future weather behavior based upon the characteristics of similar weather occurrences in past history.

The investigations have led to the conclusion that the atmosphere may be treated as a fluid envelope that surrounds the earth and, as it responds to the various forces acting upon it, engenders the formation of moving and quasi-stationary wave systems. These three-dimensional wave forms are completely defined by the observed barometic pressure patterns at the earth's surface. An analysis of daily surface pressure patterns throughout the historical record (about 60 years) reveals elements or components of these wave forms which occur systematically, and thus may be projected into the future. Such projections can be transformed into the pressure patterns with which they are identified and thus classified into the stable circulation patterns, or weather types, referred to above. It is these sequential pressure patterns which motivate the various air streams in the atmosphere, causing their interaction to produce the weather men observe.

The mathematical resolution of the behavior pattern of certain dominant features of the atmospheric circulation, related to the weather types, was attempted during World War II in an effort to determine the sequential occurrence of weather types and predict them far in the future. Results were sufficiently promising to justify the adaptation of this phase of the work to high-

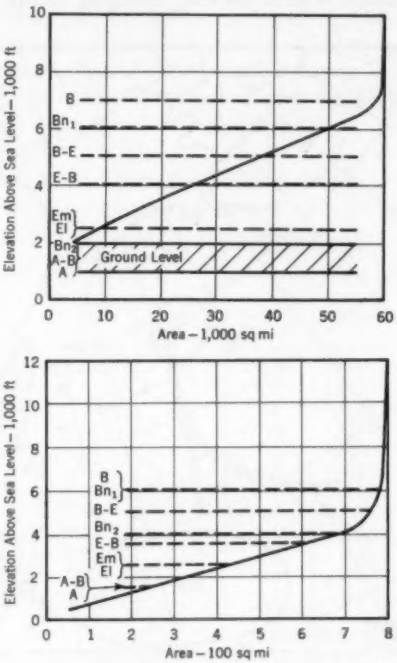


**Fig. 2. Freezing Levels of the Columbia and Lewis River Basins**

*Mean freezing levels for various weather types are superimposed on the areal-level chart of the Columbia (upper chart) and Lewis (lower chart) River basins to show the magnitude of surfaces exposed to snowmelt for each weather type.*

speed electronic computers in order to permit the adequate treatment of all possibilities and to extend the analysis ultimately to the entire historical weather archive of the Northern Hemi-

sphere. This phase of the work was not completed until recently. Programming of an electronic computer system was accomplished in the fall of 1956 (*4*). For more than 1½ years, commercial tests have been in progress utilizing information from the machine which defines the ever changing circulation patterns as they are reflected in pressure configurations at the earth's surface. Prognoses for periods of a year or more into the future have shown no deterioration with time—a characteristic which is of great importance.

Final interpretation of the prognostic charts produces weather information which can be converted into streamflow or other weather-related parameters, with tolerances acceptable to management. It has been found possible to project quantitatively cumulative influences of weather for a year or more with a high degree of accuracy and to time major weather events within economically useful limits. Thus, instead of using the lowest water year in history as a basis for dependable streamflow estimates, this method produces a forecast based upon a syn-

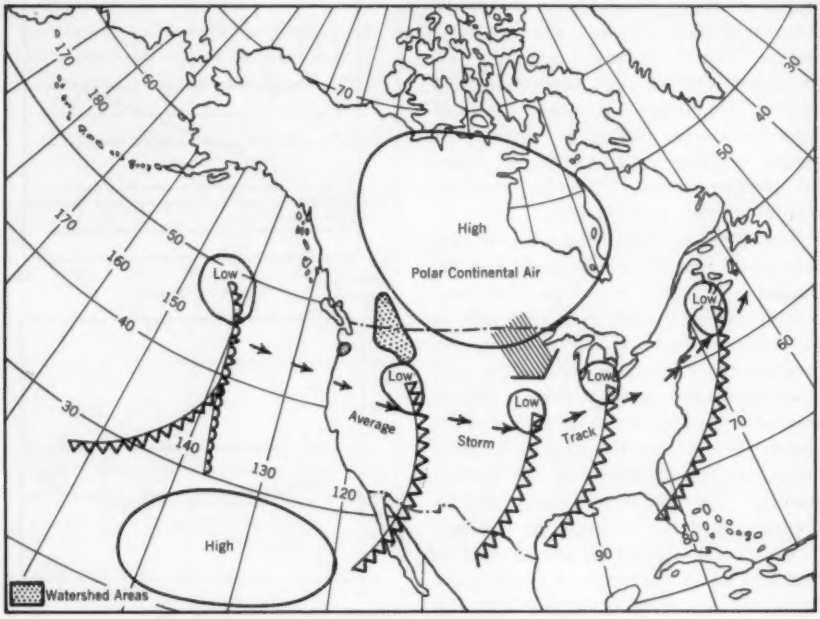


**Fig. 3. North American Weather Type *E***

*The eastern Pacific high-pressure area is quite far south and steers storms in the central part of the continent. Type* E *usually brings much rain and warming temperatures to the Lewis and Columbia watersheds. Type* E *was responsible for the warm February and high flows of 1958.*

thesis of those components of weather in past history that are expected to recur during a forecast year. Such forecasts may bear no direct relation to any single year in past history; they are a summation of parts from many years. This approach provides a physical basis for developing dependable streamflow forecasts and may ultimately eliminate the need for using the low water year in estimating firm power capabilities. By synthesizing the forecast from segments of past history which coincide with the projected weather patterns, a forecast can be made that comes closer to the mark than do purely statistical approaches.

It is now possible to go back through past streamflow years and synthesize them by utilizing matching segments from the entire historical record to synthesize any particular year. Table 3 illustrates such a synthesis for 1936–37, the critical water year. Computed inflow at Grand Coulee is within 20 per cent of observed values. Completion of this study will determine the inherent variability of such forecasts so that in subsequent years one may arrive at dependable annual inflow forecasts in which these tolerances can be allowed for. For example, the variability in the inflow during the critical winter months at Grand Coulee is more than 300 per cent between the low water year of 1937 and the high water year of 1934. Thus, if a tolerance of 15–20 per cent is arrived at in streamflow forecasts for extreme years, it will permit the determination of streamflow values of greater dependability than those derived from using the 1936–37 water year. This should introduce greater flexibility not only in power system operation, but also in the purchase of insurance policies against the occurrence of critical water shortages.

TABLE 3

*Reconstructed Estimates of Precipitation by Weather Type Sequence, 1936–37*

| Month | Weather Type | | | | | | Precipitation in Watershed—*in.* | |
|---|---|---|---|---|---|---|---|---|
| | Day of Month | | | | | | Reconstructed Estimate | Actual |
| | 5 | 10 | 15 | 20 | 25 | 30 | | |
| Oct. | B | Bn | Cl | Bn | Bn | AB | 0.7 | 0.47 |
| Nov. | A | B | B | Bn | A | | 0.6 | 0.13 |
| Dec. | B | B | Bn | A | AB | | 0.7 | 0.68 |
| Jan. | AB | A | A | A | A | | 1.3 | 0.75 |
| Feb. | El | BE | B | BE | Bs | | 1.2 | 1.03 |
| Mar. | Bs | Eh | Em | A | B | | 0.9 | 0.52 |
| Apr. | EB | B | BA | BA | B | | 1.0 | 0.93 |
| May | Bn | B | B | BA | Bn | | 0.5 | 0.97 |
| Jun. | Bn | EB | EB | B | AB | | 1.1 | 1.08 |
| Jul. | Bn | Bn | Bn | Bn | Bn | | 0.2 | 0.47 |
| Aug. | Bn | BA | Bn | B | BA | | 0.6 | 0.33 |
| Sep. | A | Bn | Bn | Bn | Bn | | 0.3 | 0.57 |
| *Totals* | | | | | | | 9.1 | 7.93 |

### Streamflow and Weather Types

In the categorizing of weather types of North America, one of the atmospheric features considered basic to an understanding of the weather patterns influencing the western United States, was the eastern extension of the Pacific Anticyclone, a semipermanent area of high barometric pressure lying off the Pacific Coast. The position and orientation of its major axis and its intensity, measured by the barometric pressure at the center, determine to a large degree the point of entry and subsequent trajectory of storm systems moving into North America from the Pacific Ocean. It was found that the North American weather patterns of historical record could be classified in terms of the oscillations of this basic atmospheric feature. It appeared that this East Pacific High, which was called a control cell, had a number of preferred positions, each one dictating the general character of storm movements into the western United States and across the country. Irrespective of the season of the year, a sequential weather pattern that influenced conditions at a particular locality for an average interval of 6 days could be determined in relation to each favored position of the Pacific High. The weather of record was classified into six basic North American weather types, which were designated *A, B, C, D, E,* and *F.* Various combinations and subclassifications of these broad categories were determined as the studies progressed.

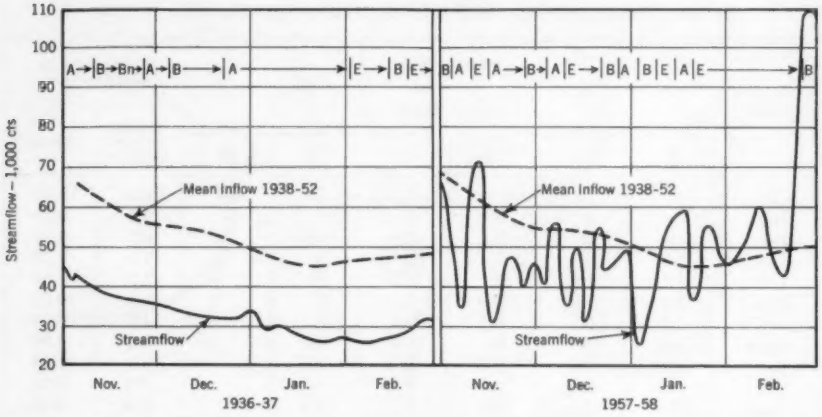


**Fig. 4. Weather Type Sequences and Streamflow Characteristics at Grand Coulee, 1936–37 and 1957–58**

*Temperature and precipitation variations for these periods are given in Fig. 5.*

The sequence of weather types during a particular season not only determines the weather of the season, but explains any radical departures from normal. Because streamflow is controlled by sequences of precipitation and temperature, direct relationships between the weather types and streamflow at key gaging stations can be developed. It is of interest here to ex-

amine streamflow–weather type relationships as they affect the critical water year, 1936–37.

*Type* A

Weather Type *A* (Fig. 1) is characterized in the winter months by surface temperatures far below freezing in the Columbia River Basin (Fig. 2); this reduces areas of melting snow and consequent streamflows. The predominance of this weather type during January 1937 produced a sharp reduction in flows during that month—a vitally important characteristic of this critical water year. A recurrence of this weather type during that period in *any* year is highly improbable because of the extremely anomalous position of its control, the Pacific Anticyclone, in the winter. It was located far north, which is a common position in summer, but most unusual in winter.

*Type* E

At the other extreme, Type *E* weather (Fig. 3) produces a combination of freezing levels high in the atmosphere (Fig. 2) and copious rainfall, which thus expose large areas of the Columbia Basin and the Pacific Northwest to melting snow. This weather type is responsible for high flows in the winter months. February 1958 had a high frequency of this weather type, which produced a marked warming and above-normal rainfall. The result was high streamflows in river basins of the Pacific Northwest and as far south as California.

It is thus possible, on the basis of projected weather types, to determine the possibility of a recurrence of the 1936–37 years. An examination of the sequence of weather types expected during the months of January and February is particularly important in this respect. An absence of weather Type *A* during this period will completely neutralize the downward trend in flows reflected in the critical year curve during these months. The occurrence of weather Type *E* will reverse it. Figures 4 and 5 show the actual weather type sequences and related weather and streamflow characteristics at Grand Coulee for the 1936–37 winter,

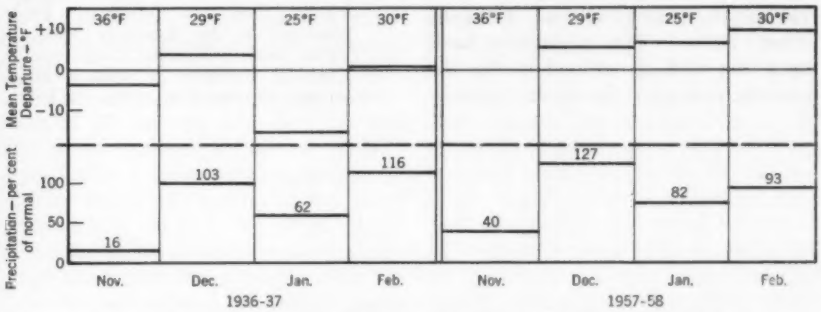


**Fig. 5. Temperature and Precipitation Variations at Grand Coulee, 1936–37 and 1957–58**

*Weather type sequences and streamflow characteristics for these periods are given in Fig. 4.*

and for the 1957–58 winter. The latter sequence exhibits infrequent and very short intervals of Type *A* but reflects much of the Type *E* characteristic, particularly during February. Therefore, instead of falling off sharply in winter, as they did in the critical water year, streamflows increased markedly over normal- or critical-year expectancies. Considering actual conditions in the fall of 1957, particularly the low water in November, a streamflow estimate made on Dec. 1 for the balance of the season and utilizing the critical water year curve in the projection would call for reduced flows during January–February in the Columbia River Basin. The projection based upon the method outlined in this discussion indicated the exact opposite, an upturn, particularly in February—a condition that actual flows later confirmed.

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# Radioactivity of Surface Waters in the United States

***Lloyd R. Setter, John E. Regnier, and Edward A. Diephaus***

*A paper presented on Jul. 13, 1959, at the Annual Conference, San Francisco, Calif., by Lloyd R. Setter, Chief; John E. Regnier, Staff Asst. to Chief; and Edward A. Diephaus, Chemist, all of Radiological Health Research Activities, Div. of Radiological Health, Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.*

MEASUREMENTS of radioactivity in water are among the many kinds of data gathered by the National Water Quality Network of USPHS (*1–3*). After a pilot network operation of 10 stations (*4*) in 1956 and 1957, 44 stations submitted weekly samples for radioactivity measurements during the last 11 months of the water year ending on Sep. 30, 1958. It is the purpose of this article to: [1] report on stream water quality with respect to radioactivity, [2] indicate some of the principal sources of radioactivity, and [3] relate radioactive runoff to rainout.* Only part of the basic radioactivity data—namely that of the Missouri River and a few stations on the Mississippi River—has been used to indicate trends and relationships that may be useful in a study of other drainage basins. Figure 1 shows the geographic distribution of the sampling stations in the network.

## Radioactivity Measurements

Every week, 1-liter grab samples of surface water collected by personnel of cooperating state and local agencies were shipped to the Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, for determinations of gross alpha and gross beta radioactivity. Each sample was separated by membrane filtration into a suspended fraction and a filtrate (dissolved) fraction (*5*). Usually, a 250- or 500-ml sample was filtered, but when the water had a high concentration of suspended or dissolved solids, a much smaller sample was taken. The best sample size for a pan area of 20 sq cm had a dry-solid weight of about 200 mg for beta counting and less than 100 mg for alpha counting. The acidified (pH 4–5) filtrate was reduced in volume by evaporation in a pyrex beaker and the residue transferred to an aluminum counting pan. The sample was then oven dried (103°C), weighed, and counted, generally 1–2 weeks after sample collection.

No correction was made for radioactive decay to the time of collection, but decay measurements were made on some of the more radioactive samples. For example, the beta activity of samples of the Columbia River near the Hanford Atomic Products Operation Reservation in Washington usually had half-lives of 14–15 days. Much of the

*Fallout is radioactive debris, usually from a nuclear detonation, that has been deposited on the earth after having been airborne. Special kinds of fallout are: dry fallout, rainout, and snowout.

**Fig. 1. USPHS National Water Quality Network—1958**

*The map shows the geographic distribution of the 44 sampling stations (solid circles) in the network. Samples of water from these stations were collected and studied during the last 11 months of the water year ending on Sep. 30, 1958.*

short-lived radioactivity reported by McConiga and Cluskey (*6*) as being discharged from the Hanford operations (Table 1) would have decayed appreciably by the time the samples arrived at Cincinnati.

TABLE 1

*Radionuclides in Coolant Water From the Hanford Reactor*

| Radionuclide | Half-Life *days* | Radionuclide | Half-Life *days* |
|---|---|---|---|
| $Cu^{64}$ | 0.533 | $Ba^{140}$ | 12.8 |
| $Na^{24}$ | 0.625 | $P^{32}$ | 14.5 |
| $As^{76}$ | 1.1 | $Cr^{51}$ | 27.0 |
| $Np^{239}$ | 2.3 | $Sr^{89}$ | 54.0 |
| $Sc^{46}$ | 3.4 | $Zn^{65}$ | 245.0 |

## Water Quality

Initially, both alpha and beta measurements were made until a background level of alpha activity was established. The frequency of tests for alpha activity was then reduced to once a month at most sampling stations. With some exceptions, the alpha activity did not exceed three standard deviations of the counting error.

The beta activity at each sampling station compared favorably from week to week until the spring of 1958, with an occasional high activity, particularly in the suspended fraction. The high beta activities frequently but not always corresponded to high concentrations of suspended solids in the sample. During the succeeding 6 months,

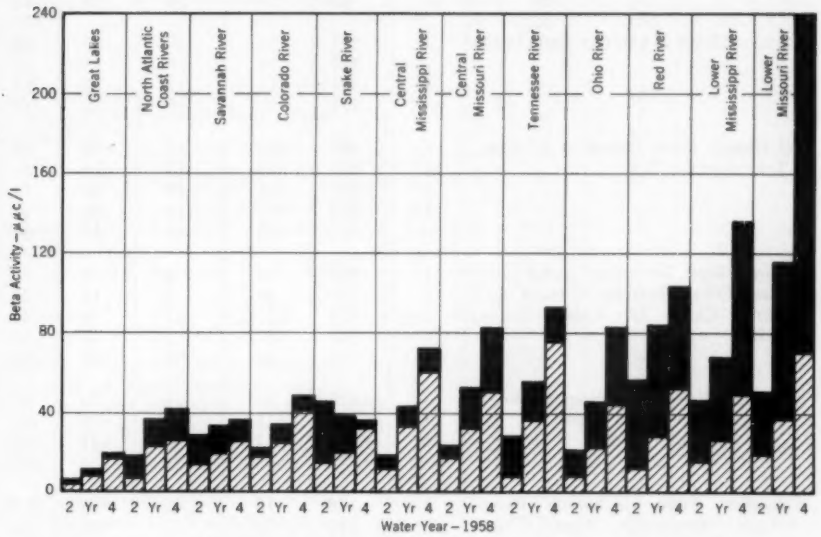


**Fig. 2. Beta Activity of Surface Waters in Various Drainage Areas**

*Striped bars represent dissolved solids in water; black bars, suspended solids. The numeral 2 in the abscissa means the average for the second quarter (January–March) of the water year ending on Sep. 30, 1958. The numeral 4 means the average for the fourth quarter (July–September). "Yr" means the average for 11 months of the water year (Nov. 1, 1957, to Sep. 30, 1958).*

TABLE 2

*Radiologic Analyses of Water Samples From Various Drainage Areas*

| Drainage Area | Quarter* | Avg Concn. of Solids *mg/l* | | Avg Beta Activity *μμc/l* | | |
|---|---|---|---|---|---|---|
| | | Dissolved | Suspended | Suspended | Dissolved | Total |
| *Great Lakes*, including Buffalo, N.Y.; Detroit, Mich.; Duluth, Minn. | 1 | 118 | 17 | 4 | 8 | 12 |
| | 2 | 152 | 19 | 2 | 4 | 6 |
| | 3 | 147 | 12 | 5 | 11 | 16 |
| | 4 | 159 | 14 | 2 | 17 | 19 |
| | yr | 144 | 16 | 3 | 8 | 11 |
| *N. Atlantic Coast Rivers*,† including Lowell, Mass.; Poughkeepsie, N.Y.; Hagerstown, Md.; Great Falls, Md.; Philadelphia, Pa. | 1 | 161 | 31 | 9 | 16 | 25 |
| | 2 | 126 | 49 | 11 | 7 | 18 |
| | 3 | 124 | 44 | 16 | 43 | 59 |
| | 4 | 157 | 18 | 15 | 26 | 41 |
| | yr | 142 | 36 | 13 | 23 | 36 |
| *Savannah River*, including N. Augusta, Ga.; Savannah, Ga. | 2 | 95 | 51 | 14 | 14 | 28 |
| | 3 | 84 | 33 | 16 | 17 | 33 |
| | 4 | 486 | 22 | 11 | 25 | 36 |
| | yr | 88 | 35 | 14 | 19 | 33 |
| *Tennessee River* at Chattanooga, Tenn. | 2 | 105 | 40 | 20 | 8 | 28 |
| | 3 | 125 | 24 | 20 | 25 | 45 |
| | 4 | 141 | 12 | 17 | 75 | 92 |
| | yr | 124 | 25 | 19 | 36 | 55 |
| *Rio Grande River*, including El Paso, Tex.; Laredo, Tex. | 1 | 691 | 286 | 32 | 26 | 58 |
| | 2 | 621 | 218 | 17 | 14 | 31 |
| | 3 | 631 | 325 | 29 | 45 | 74 |
| | 4 | 545 | 913 | 114 | 80 | 194 |
| | yr | 622 | 436 | 48 | 41 | 89 |
| *Colorado River*, including Grand Junction, Colo.; Boulder City, Colo.; Parker Dam, Ariz.-Calif.; Yuma, Ariz. | 1 | 833 | 44 | 6 | 10 | 16 |
| | 2 | 741 | 36 | 4 | 18 | 22 |
| | 3 | 612 | 121 | 17 | 30 | 47 |
| | 4 | 868 | 62 | 7 | 41 | 48 |
| | yr | 764 | 66 | 9 | 25 | 34 |
| *Arkansas River*, including Coolidge, Kan.; Ponca City, Okla. | 2 | 3,820 | 52 | 14 | 76 | 90 |
| | 3 | 1,910 | 615 | 169 | 128 | 197 |
| | 4 | 1,410 | 613 | 180 | 144 | 324 |
| | yr | 2,379 | 428 | 121 | 116 | 237 |
| *Columbia River*, including Pasco, Wash.; Bonneville, Wash.; Clatskanie, Ore.‡ | 1 | 148 | 18 | 42 | 785 | 827 |
| | 2 | 210 | 31 | 72 | 684 | 756 |
| | 3 | 115 | 31 | 60 | 260 | 320 |
| | 4 | 128 | 17 | 43 | 385 | 428 |
| | yr | 150 | 24 | 54 | 529 | 583 |

* First, second, third, and fourth quarters of the water year, from Oct. 1, 1957, to Sep. 30, 1958.
† Delaware, Merrimack, Hudson, and Potomac.
‡ Beaver Army Terminal.

TABLE 2

*Analyses of Water Samples (Contd.)*

| Drainage Area | Quarter* | Avg Concn. of Solids *mg/l* | | Avg Beta Activity *μμc/l* | | |
|---|---|---|---|---|---|---|
| | | Dissolved | Suspended | Suspended | Dissolved | Total |
| *Snake River*, including Weiser, Idaho; Wawawai, Wash. | 1 | 286 | 99 | 17 | 13 | 30 |
| | 2 | 215 | 134 | 30 | 15 | 45 |
| | 3 | 130 | 72 | 6 | 22 | 28 |
| | 4 | 280 | 24 | 4 | 32 | 36 |
| | yr | 228 | 82 | 18 | 20 | 38 |
| *Red River* at Alexandria, La. | 1 | 222 | 891 | 56 | 16 | 72 |
| | 2 | 275 | 585 | 44 | 12 | 56 |
| | 3 | 292 | 583 | 68 | 33 | 101 |
| | 4 | 259 | 226 | 51 | 52 | 103 |
| | yr | 260 | 499 | 55 | 28 | 83 |
| *Ohio River*, including E. Liverpool, Ohio; Huntington, W.Va.; Cincinnati, Ohio; Evansville, Ind.; Cairo, Ill. | 1 | 282 | 132 | 14 | 15 | 29 |
| | 2 | 217 | 90 | 13 | 8 | 21 |
| | 3 | 209 | 109 | 26 | 20 | 46 |
| | 4 | 253 | 120 | 38 | 44 | 82 |
| | yr | 240 | 113 | 23 | 22 | 45 |
| *Central Missouri River*, including Williston, N.D.; Bismarck, N.D.; Yankton, S.D. | 1 | 442 | 89 | 12 | 27 | 39 |
| | 2 | 453 | 48 | 6 | 17 | 23 |
| | 3 | 415 | 315 | 37 | 35 | 62 |
| | 4 | 402 | 290 | 32 | 50 | 82 |
| | yr | 428 | 186 | 22 | 32 | 52 |
| *Lower Missouri River*, including Omaha, Neb.; St. Joseph, Mo.; Kansas City, Kan.; St. Louis, Mo. | 1 | 423 | 228 | 24 | 26 | 50 |
| | 2 | 428 | 370† | 31 | 19 | 50 |
| | 3 | 408 | 716 | 85 | 34 | 119 |
| | 4 | 382 | 842 | 170 | 70 | 240 |
| | yr | 410 | 554 | 78 | 37 | 115 |
| *Central Mississippi River*, including Red Wing, Minn.; Dubuque, Iowa; Burlington, Iowa | 1 | 282 | 25 | 9 | 27 | 36 |
| | 2 | 274 | 24 | 6 | 12 | 18 |
| | 3 | 274 | 85 | 15 | 32 | 47 |
| | 4 | 237 | 30 | 12 | 60 | 72 |
| | yr | 267 | 41 | 11 | 33 | 44 |
| *Lower Mississippi River*, including E. St. Louis, Ill.; Cape Girardeau, Mo.; W. Memphis, Ark.; Vicksburg, Miss.; New Orleans, La. | 1 | 211 | 91 | 9 | 7 | 16 |
| | 2 | 276 | 226 | 30 | 16 | 46 |
| | 3 | 251 | 232 | 42 | 30 | 72 |
| | 4 | 274 | 368 | 87 | 49 | 136 |
| | yr | 253 | 229 | 42 | 26 | 68 |

* First, second, third, and fourth quarters of the water year, from Oct. 1, 1957, to Sep. 30, 1958.
† One test for suspended solids excluded.

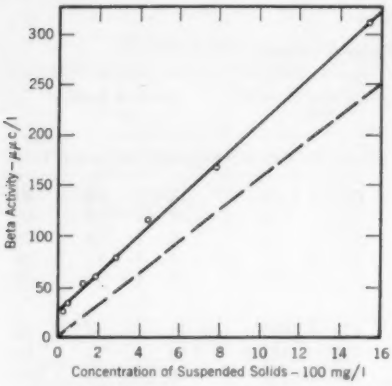


**Fig. 3. Relationship Between Radioactivity and Concentration of Suspended Solids in Stream Surface Water**

*The solid and dashed curves represent total beta activity and suspended beta activity, respectively.*

from April through September (the third and fourth quarters), the fluctuations in concentration of suspended solids and the fluctuations of beta activity in both the dissolved and, particularly, the suspended fractions were much greater. In order to consolidate the data, the average results of weekly tests over each 3-month period for a group of sampling stations constituting a drainage area were determined (Table 2). The January–March quarter, the July–September quarter, and the yearly results are shown in Fig. 2.

The data in Table 2 reveal that during the first and second quarters (Oct. 1, 1957, to Mar. 31, 1958) the total beta activity was generally less than for the last two quarters by a factor of two or more, with the exception of beta activity in the Columbia River and Snake River basins. The station groups representing those on or just below impoundments have the least total beta activity because of: [1] the settlement of suspended matter having associated beta activity; [2] the decay of short-lived radionuclides; and, possibly, [3] the dilution by uncontaminated water. The impounded waters are: the Great Lakes, Savannah River, Tennessee River, Colorado River, Central Missouri River, and, to a lesser degree, the Ohio River and Central Mississippi River. The Columbia River, impounded at both Pasco and Bonneville, Wash., contains small amounts of suspended solids, relatively small amounts of suspended beta activity, but relatively large amounts of dissolved beta activity. These differences arise from the discharge of nuclear-reactor coolant water above the Pasco sampling station.

The dissolved solids or filtrate residues from the various areas provide interesting information. The dissolved solids vary in concentration from a quarterly average of about 100 mg/l in the Savannah River to 3,800 mg/l in the Arkansas River. The Rio Grande, Colorado, and Missouri rivers also have water with high concentrations of dissolved solids (400–800 mg/l). Some of these samples

TABLE 3

*Concentrations of Suspended Solids Correlated With Beta Activity at Unimpounded-Water Stations*

| Concn. Range of Suspended Solids *mg/l* | No. of Samples | Avg Concn. of Suspended Solids *mg/l* | Avg Total Beta Activity *μμc/l* |
|---|---|---|---|
| 0–29 | 19 | 26 | 27 |
| 30–69 | 28 | 49 | 32 |
| 70–149 | 62 | 124 | 52 |
| 150–249 | 29 | 184 | 60 |
| 250–349 | 37 | 285 | 78 |
| 350–549 | 61 | 444 | 115 |
| 550–999 | 40 | 786 | 167 |
| >1,000 | 38 | 1,540 | 311 |

frequently show apparent, large concentrations of dissolved beta activities. Much of this apparent activity may be the result of the counting error multiplied by the dilution factor. For example, 100 ml of sample containing 4,000 mg/l of solids with a beta activity equal to instrument background would be recorded as having an activity of about 65±65 $\mu\mu$c/l. In general, the lower the concentration of solids in the sample, the smaller the counting error. For the 500-ml samples, representing a majority of the samples analyzed, the counting error at the 95 per cent confidence level was less than 10 $\mu\mu$c/l at an activity level equal to instrument background.

The waters of the Missouri, lower Mississippi, Ohio, Red, and Arkansas rivers, and possibly the Tennessee River, were most heavily contaminated by rainout during the last 6 months of the year ending Sep. 30, 1958. It is noted that the dissolved beta activity in the Chattanooga samples during the fourth quarter (July–September) is similar to that in other drainage areas in the central United States. Consequently, it could be that this activity is rainout from which the suspended activity has separated by sedimentation, even though the value may also reflect some contribution from Oak Ridge operations.

## Relationships of Suspended Matter to Beta Activity

Impounded waters have a high ratio of dissolved to total activity and a low concentration of suspended matter. For example, the 45 samples from Yankton, S.D., collected just below the Gavins Point Reservoir, had an average concentration of suspended solids of 24 mg/l and a total beta activity of 35 $\mu\mu$c/l. Of the total activity, 80 per cent was in the filtrate. In contrast, the test results of weekly samples from unimpounded-water stations (Williston, N.D.; Omaha, Neb.; St. Joseph, Mo.; Kansas City, Kan.; St. Louis, Mo.; East St. Louis, Ill.; Cape Girardeau, Mo.; and West Memphis, Ark.) were grouped according to concentration range of suspended solids (Table 3, Fig. 3).

Figure 3 shows the relationship between the concentration of suspended solids and the amount of beta activity. Although the slope of the curve and the magnitude of the beta activity for zero suspended solids might vary with the degree of fallout, the trend curve provides circumstantial evidence that radioactive runoff is proportional to rain intensity, because the concentra-

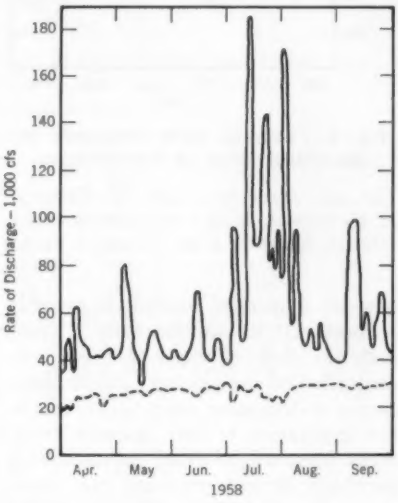


**Fig. 4. Average Daily Discharge of Missouri River at Two Stations**

*The solid curve represents the discharge at Kansas City, Kan.; the dashed curve, the discharge at Yankton, S.D.*

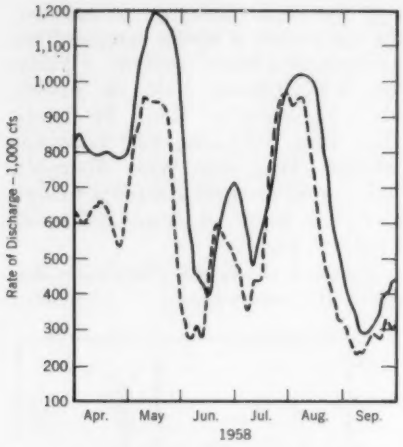


**Fig. 5. Average Daily Discharge of Mississippi River at Two Stations**

*The solid curve represents the discharge at Vicksburg, Miss.; the dashed curve, the discharge at West Memphis, Ark.*

tion of suspended matter is roughly proportional to rain intensity. Thus, both the flow of water and the concentration of radioactivity reach maximums at the same time. The practical implication is that a water treatment plant might avoid contamination problems by not pumping raw water during the peak flow of highly radioactive water.

## Radioactivity Load

The radioactivity load or the quantity of radioactivity carried by a stream at a sampling station is the product of water flow and concentration of radioactivity. Between sampling stations, the load is changed by new supply and by hydrologic factors such as stream holdup or detention in natural or artificial impoundments permitting decay, and natural (physical, chemical, and biological) removal of activity from the aqueous phase. It is beyond the scope of this article to deal at length with these factors for each of the drainage areas. Select reaches of the Missouri and Mississippi rivers have been chosen to illustrate some of the relationships believed to be significant. These areas were selected primarily because the beta activities in surface waters were highest and because data on fallout or rainout (the principal sources of surface water contamination) were somewhat more complete for these areas.

Data on the central and lower Missouri River and the lower Mississippi River (*7*) are given in Table 4. Figure 4 shows the average daily discharge of the Missouri River (*8*) at Yankton, S.D., below six main-stem dams forming the Fort Peck, Garrison, Oahe, Fort Randall, and Gavins Point reservoirs with a potential storage capacity of about 70,000,000 acre-ft (*9*). Also shown is the average daily discharge at Kansas City, Kan., which in-

TABLE 4

*Geographic Data on Missouri and Mississippi River Basins*

| Station | Drainage Area *sq mi* | Distance to Mouth *mi* | Elevation Above Sea Level *ft* |
|---|---|---|---|
| *Central Missouri River* | | | |
| Williston, N.D. | 164,500 | 1,644 | 1,863 |
| Bismarck, N.D. | 186,400 | 1,377 | 1,618 |
| Yankton, S.D. | 279,500 | 841 | 1,159 |
| *Lower Missouri River* | | | |
| Omaha, Neb. | 322,800 | 642 | 958 |
| St. Joseph, Mo. | 424,300 | 471 | 788 |
| Kansas City, Kan. | 489,200 | 385 | 716 |
| Herman, Mo. | 528,300 | 97 | 481 |
| St. Louis, Mo. (Missouri River total) | 530,000 | 36 | 379* |
| *Mississippi River* | | | |
| E. St. Louis, Ill. | 701,000 | 1,166 | 379 |
| Cap Girardeau, Mo.† | 717,200 | 1,020 | 304 |
| West Memphis, Ark. | 932,800 | 726 | 183 |
| Vicksburg, Miss. | 1,144,500 | 431 | 46 |
| New Orleans, La. | 1,243,600 | 105 | 0 |

* Taken as equal to that of E. St. Louis, Ill.
† Based on data from nearby Thebes, Ill.

cludes the uncontrolled flow of the Platte, Kansas, and other tributary streams. It is noted that the discharge at Yankton remained relatively steady at 20,000–30,000 cfs, whereas the discharge at Kansas City was characteristic of the uncontrolled flow of local tributaries superimposed on the controlled flow passing Yankton.

In Fig. 5, the discharge curve of the Mississippi River (*8*) at West Memphis, Ark., is compared to the curve for Vicksburg, Miss., 295 mi downstream. The curves at both these stations followed similar patterns, with a time lag of 3–10 days and a median of 4–5 days, indicating a rate of flow less than 3 mph (*10*).

The radioactivity (beta) load in curies per month was computed by three methods to obtain the monthly load for Cape Girardeau and Vicksburg on the Mississippi River. Method A consisted of computing the average beta load from the discharge and activity on the days of sampling. In Method B, the average monthly activity and the average monthly discharge (Table 5) were used. Finally, in Method C the beta load was computed as the mean of the Vicksburg beta load (Method A) and the West Memphis beta load (Method A), prorated to an area equal to the Vicksburg drainage area. The results are shown in Table 6.

The beta load for the 6-month period amounted to 19–20 kc at Cape Girardeau and 27–30 kc for Vicksburg by either method of calculation, even although both the flow and beta activity fluctuated greatly. A review of the monthly beta load indicates that either method of calculation was fairly adequate and particularly good for a 6-month period. To obtain a representative sampling of smaller rivers of uncontrolled flow or highly fluctuating flow, such as the Missouri River below Yankton, it is suggested that daily or more frequent samples be studied for radioactivity measurements.

The beta load of the Missouri River (Table 7) was determined from the

TABLE 5

*Average Monthly Discharge at USGS Gaging Stations Near Sampling Points*

| Month* | Rate of Discharge—*1,000 cfs* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Williston, N.D. | Bismarck, N.D. | Yankton, S.D. | Omaha, Neb. | St. Joseph, Mo. | Kansas City, Kan. | Herman, Mo. | Thebes, Ill. | Vicksburg, Miss. |
| Oct. | 14.67 | 14.78 | 29.90 | 30.30 | 36.37 | 42.33 | 46.83 | 91.4 | 260 |
| Nov. | 14.60 | 9.84 | 9.55 | 14.90 | 21.57 | 25.99 | 33.61 | 103.4 | 574 |
| Dec. | 12.05 | 11.31 | 9.87 | 9.35 | 15.58 | 18.22 | 34.30 | 112.2 | 865 |
| Jan. | 11.78 | 14.19 | | 9.65 | 14.27 | 16.42 | 24.15 | 98.1 | 715 |
| Feb. | 11.54 | 13.23 | 8.70 | 10.84 | 17.02 | 20.22 | 32.12 | 72.8 | 595 |
| Mar. | 14.77 | 15.37 | 9.80 | 12.08 | 26.20 | 41.40 | 103.80 | 231.1 | 627 |
| Apr. | 16.15 | 19.07 | 23.19 | 25.13 | 37.00 | 45.12 | 73.24 | 179.3 | 806 |
| May | 21.71 | 20.77 | 26.35 | 26.59 | 36.39 | 48.81 | 73.99 | 162 | 1,070 |
| Jun. | 34.59 | 29.37 | 27.80 | 18.15 | 35.62 | 46.90 | 71.64 | 186 | 565 |
| Jul. | 20.38 | 14.73 | 25.93 | 27.17 | 58.53 | 94.67 | 179.80 | 328 | 682 |
| Aug. | 15.43 | 17.68 | 28.19 | 27.19 | 44.01 | 64.25 | 127.20 | 264 | 849 |
| Sep. | 13.70 | 29.70 | 28.94 | 28.25 | 43.80 | 61.34 | 76.31 | 125 | 358 |

* October through December 1957; January through September 1958.

TABLE 6

*Radioactivity (Beta) Load in the Mississippi River for 6 Months During 1958*

| Month | Radioactivity Load—*curies* | | | | |
|---|---|---|---|---|---|
| | Cape Girardeau | | Vicksburg | | Vicksburg & W. Memphis |
| | Method A* | Method B† | Method A* | Method B† | Method C‡ |
| Apr. | 645 | 790 | 3,120 | 3,135 | 3,128§ |
| May | 750 | 675 | 5,350 | 5,430 | 4,185 |
| Jun. | 3,280 | 3,220 | 3,860 | 3,440 | 3,456 |
| Jul. | 9,500 | 10,240 | 5,490 | 5,685 | 8,030 |
| Aug. | 4,050 | 3,980 | 8,880 | 9,395 | 6,950 |
| Sep. | 1,135 | 835 | 2,530 | 2,100 | 1,935 |
| *6-month total* | 19,306 | 19,740 | 29,230 | 29,185 | 27,685 |
| A ÷ B | 0.98 | | 1.00 | | |
| B ÷ C | | | | 1.05 | |

* Average product of discharge and activity on $x$ sampling days per month.
† Product of average monthly discharge and average monthly activity.
‡ Average radioactivity load at Vicksburg and load at West Memphis prorated to drainage area at Vicksburg.
§ Radioactivity load for April assumed to be the average of A and B.

average monthly activity and the monthly river flow. The beta load at Kansas City was substantially higher than at St. Louis in May and September and almost identical to that at St. Louis in April and August. This may be the result of nonrepresentative sampling of the river. The average beta load of both stations was used to compute subsequent radioactive runoff.

During the 6-month period of study, water containing 1,703 c passed Williston and flowed into the Garrison Reservoir. Only 535 c passed Yankton, an overall decrease in radioactivity of 68.5 per cent between the two stations. Sedimentation, which reduces the suspended activity, accounted for much of this decrease. Physical decay may account for a substantial reduction in activity, for the theoretical detention period in the Garrison Reservoir (capacity 9,000,000–10,000,000 acre-ft) and the Oahe, Fort Randall, and Gavins Point reservoirs (capacity less than one-half of Garrison) is an average of 330 days (Table 8). If the period of time that water travels through the reservoir is 50–100 per cent of the theoretical detention period, radioactivity may remain in the reservoir for 5.5–11 months. If a mean velocity of flow of 2 mph is assumed for the Missouri and Mississippi rivers (*10*) below Yankton, the theoretical travel time of river water to New Orleans would be about 40 days, during which period 3-month-old bomb debris would undergo about 30 per cent decay, as compared to about 60 per cent decay for 1-month-old bomb debris.

TABLE 7

*Radioactivity (Beta) Load in the Missouri River for 6 Months During 1958*

| Station | Drainage Area *sq mi* | Radioactivity Load—*curies* | | | | | |
|---|---|---|---|---|---|---|---|
| | | Apr. | May | Jun. | Jul. | Aug. | Sep. |
| Williston, N.D. | 164,500 | 126 | 206 | 414 | 548 | 224 | 185 |
| Yankton, S.D. | 279,500 | 53 | 74 | 92 | 175 | 88 | 53 |
| Omaha, Neb. | 322,800 | 164 | 131 | 105 | 391 | 124 | 108 |
| St. Joseph, Mo. | 424,300 | 331 | 226 | 201 | 1,765 | 614 | 334 |
| Kansas City, Kan. | 489,200 | 447 | 977 | 413 | 4,628 | 1,548 | 873 |
| Herman, Mo. (St. Louis) | 528,200 | 456 | 527 | 972 | 5,764 | 1,542 | 655 |
| Kansas City & St. Louis—*avg* | 508,700 | 452 | 752 | 693 | 5,196 | 1,545 | 764 |
| Cape Girardeau, Mo. | 717,200 | 788 | 675 | 2,034 | 7,508 | 3,982 | 835 |
| Vicksburg, Miss. | 1,044,000 | 3,135 | 5,433 | 3,442 | 5,685 | 9,395 | 2,101 |

**Radioactive Rainout and Runoff**

The radioactivity in the Mississippi River, which was contributed by local tributary areas of the drainage basin, was derived from the beta load carried to each of the sampling stations shown in Table 6. These tributary contributions were divided by the tributary drainage area to obtain radioactive runoff for an evaluation of geographic distribution and a comparison of radioactive runoff with rainout. The beta runoff data, in millimicrocuries per square meter per month, are shown in Table 9. Included in the table is the beta runoff for Yankton, based on the total upstream drainage area. The beta runoff at Yankton is less than the beta runoff at Williston because of sedimentation and radioactive decay in reservoirs. A comparison of beta runoff from various areas indicates that, with some exceptions, the runoff is greatest in the lower Missouri River area, next greatest in the central Mississippi River area, and least for the area above Williston, except during the month of June.

Rainout data (*11*), presented in Table 10, can be compared with runoff from various areas during a given month or period. Generally, beta rainout is about 100 times greater than beta runoff. More specifically, if the average 6-month fallout at Cheyenne, Wyo.; Pierre, S.D.; Minneapolis, Minn.; and Iowa City, Iowa, of 912 mμc/sq m can be considered representative of the Missouri River above Omaha, Neb., then the 6-month runoff of 3–4.4 mμc/sq m represents only 0.3–0.5 per cent of the rainout. Similarly, if the average rainout at Iowa City, Iowa; Topeka, Kan.; Oklahoma City, Okla.; Little Rock, Ark.; Jefferson City, Mo.; Springfield, Ill.; Indianapolis, Ind.; and Cincinnati, Ohio, is representative of rainout in the lower Missouri River area, then the 6-month beta runoff of 9–22 mμc/sq m represents 0.6–1.5 per cent of the 1,398 mμc/sq m rainout. When the 6-month beta runoff from the Mississippi River drainage area above Vicksburg and the average 6-month rainout for stations listed in Table 10 are considered, the 10.82 mμc/sq m of runoff is 0.85 per cent of the rainout.

*Radioactivity Losses*

This loss of rain radioactivity is the result of radioactivity decay of nuclear-bomb debris during the time it is detained in reaching the watercourse, in passing through the reservoirs, or in moving downstream. It is estimated that 20–50 per cent of the rain activity would have decayed within 2 weeks. Rain radioactivity is also lost by attachment or adsorption on surfaces of living plants, soil, organic matter, or clay. Presumably, the poorer the cover crop (if there is one), the more

TABLE 8

*Detention of Water by Reservoirs for 6 Months During 1958* *

| Month | Detention Period—*days* | | |
|---|---|---|---|
| | Garrison Reservoir† | Fort Randall Reservoir‡ | Total§ |
| Apr. | 250 | 103 | 353 |
| May | 224 | 88 | 312 |
| Jun. | 207 | 85 | 292 |
| Jul. | 344 | 91 | 435 |
| Aug. | 291 | 93 | 384 |
| Sep. | 150 | 59 | 209 |
| *Avg* | 244 | 86 | 330 |

* Tentative estimates from US Army Corps of Engineers' weekly reports on dam operations.

† Between Williston and Bismarck. Fort Peck Reservoir, on the main stem of the Missouri River above Williston, has a storage capacity approximately twice that of the Garrison Reservoir.

‡ Between Bismarck and Yankton, including the Gavins Point Reservoir and, during August and September, the new Oahe Reservoir.

§ From Williston to Yankton.

intense the rainfall; and the steeper the hydraulic gradient, the higher the fraction of rainout that will appear as runoff. Although living plants trap some of the activity, no extraordinary concentrations have been observed. Finally, radioactivity is lost as the result of the many natural and artificial impoundments from ponds, lakes, and large reservoirs, which cause some of the suspended activity to be removed by sedimentation.

Rainout is not the only cause of surface water contamination, although it appears to be the major one. Numerous industrial users of isotopes, medical and research institutions, and AEC contractors undoubtedly produce liquid wastes that are discharged into streams, but it is relatively difficult to distinguish this kind of contamination from fallout contamination, particularly on the basis of gross beta activity.

Although the surface waters of the United States have readily measurable levels of radioactivity, its physical nature is usually characteristic of the radioactivity of bomb debris—that is, composed of mixed fission products that should be interpreted as having less significance than the unknown or most hazardous radionuclides (*12*). Furthermore, much of this activity is associated with suspended matter that can be quite readily removed by conventional water treatment (chemical coagulation and sand filtration) (*13*).

### *Radioactivity in Foods*

The discrepancy between the amount of radioactivity in rain and that in runoff confirms previous findings (*14*) and indicates that the bulk of radioactivity in rain, not lost by decay, remains on the surface it falls on. The distribution of this activity and the extent to which surface contamination is ingested, are important factors contributing to the total radiation exposure of humans. Some of these contaminated surfaces may be of garden produce or grasses serving as pasture for milch cows. Other crops contaminated by direct deposition or by the translocation of contaminated soil (dust) may be harvested for sale or stored and used for fodder. Food may

TABLE 9

*Monthly Radioactive Runoff in Various Drainage Areas—1958*

| Drainage Area | Radioactive Runoff—*mμc/sq m* | | | | | | |
|---|---|---|---|---|---|---|---|
| | Apr. | May | Jun. | Jul. | Aug. | Sep. | 6-Month Total |
| Headwater to Williston | 0.03 | 0.48 | 0.97 | 0.29 | 0.53 | 0.43 | 3.00 |
| Headwater to Yankton | 0.07 | 0.10 | 0.13 | 0.24 | 0.12 | 0.07 | 0.73 |
| Yankton to Omaha | 0.99 | 0.51 | 0.12 | 1.93 | 0.32 | 0.49 | 4.36 |
| Omaha to St. Joseph | 0.64 | 0.36 | 0.36 | 5.23 | 1.86 | 0.86 | 9.31 |
| St. Joseph to Herman | 0.45 | 1.96 | 1.83 | 12.76 | 3.46 | 1.60 | 22.06 |
| Headwater to Cape Girardeau* | 0.69 | 1.23† | 1.35† | 4.72 | 4.98 | 1.45 | 14.42 |
| Cape Girardeau to Vicksburg | 2.77 | 4.82 | 2.47 | 2.15 | 6.40 | 1.50 | 15.81 |
| Total area to Vicksburg | 1.16 | 2.01 | 1.27 | 2.10 | 3.47 | 0.78 | 10.82 |

* Headwater of Mississippi River to Cape Girardeau, exclusive of Missouri River.
† Adjusted values, the result of taking part of the June discharge and adding it to the May discharge.

also be contaminated by plant metabolism. It may be anticipated that the ratio of metabolized radioactivity to foliar deposition will increase with the cessation of nuclear tests and further cleansing of the atmosphere. The rather close relationship, however, between the monthly rainout deposition and the concentration of five radionuclides in milk from the Cincinnati and St. Louis areas (*15*) indicates that foliar deposition rather than plant metabolism (Table 11 and Fig. 6) is significant.

Particularly in 1958, the major deposition of rainout occurred in the big crop-producing area during the entire growing season. Thus, for the 6-month period of April through September, 77 per cent of the rainout and 80 per cent of the beta runoff occurred in May, June, July, and August, the 4 months that correspond to the time of hay and grain harvesting and heavy pasturing in the central Mississippi-Missouri River farm land.

## Summary

The radioactivity measurements of weekly samples of surface water from 44 stations on the principal river basins of the United States were summarized for the 11-month period ending Sep. 30, 1958. The investigations showed that insignificant increases of beta activity over normal background occurred in the period from November 1957 through March 1958, with a marked increase in activity levels in the period from April through September 1958. Peak values occurred in July.

TABLE 10

*Monthly Radioactive Rainout at Sampling Stations in the Upper and Lower Missouri River Areas* *

| Stations | Radioactive Rainout—*mμc/sq m* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | 6-Month Total† |
| Cheyenne, Wyo. | 77 | 33 | 116 | 161 | 695 | 158 | 52 | 1,215 |
| Pierre, S.D. | | 54 | 48 | 138 | 97 | 32 | 3 | 372 |
| Minneapolis, Minn. | 2 | 206 | 52 | 127 | 217 | 251 | 28 | 881 |
| Iowa City, Iowa | 1 | 92 | 72 | 138 | 740 | 73 | 65 | 1,180 |
| Upper Missouri River area—*avg* | 27 | 96 | 72 | 141 | 437 | 128 | 37 | 912 |
| Indianapolis, Ind. | | 84 | 112 | 156 | 589 | 168 | 45 | 1,154 |
| Springfield, Ill. | | 146 | 106 | 559 | 701 | 134 | 37 | 1,683 |
| Topeka, Kan. | 56 | 225 | 98 | 589 | 659 | 112 | 93 | 1,776 |
| Jefferson City, Mo. | | 180 | 157 | 333 | 1,345 | 104 | 46 | 2,165 |
| Little Rock, Ark. | 102 | 308 | 137 | 158 | 300 | 101 | 66 | 1,070 |
| Oklahoma City, Okla. | 35 | 28 | 43 | 153 | 160 | 99 | 26 | 509 |
| Cincinnati, Ohio | 85 | 252 | 215 | 260 | 675 | 170 | 74 | 1,646 |
| Lower Missouri River area—*avg* | 56 | 164 | 118 | 293 | 646 | 120 | 56 | 1,398 |
| All stations—*avg* | 43 | 139 | 105 | 252 | 562 | 127 | 59 | 1,234 |

* Summary data of National Radiation Surveillance Network Reports.
† Sum of April to September 1958.

Of more than 1,500 samples, only two exceeded 800 $\mu\mu$c/l total activity; however, 119 suspended-solid samples were in excess of 100 $\mu\mu$c/l, and 61 dissolved-solid samples had activities greater than this same value. These were exclusive of samples from Columbia River stations, where values

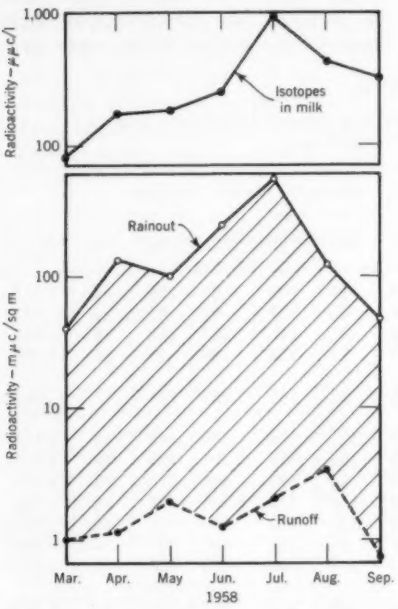


**Fig. 6. Radioactivity in Rainfall, Runoff, and Milk**

*The shaded area between "rainout" and "runoff" represents radioactive deposits on soil and foliage. Additional data on radioactivity in milk are given in Table 11.*

are generally higher because of short-lived wastes discharged at Hanford. Alpha activity levels of these surface waters were generally equal to natural background for the period covered.

The limitations in determining the radioactivity of waters with high concentrations of solids were recognized. The high activity resulting from solids and a correlation of suspended solids to total activity were studied.

Sedimentation in reservoirs (impounded waters) accounted for much of the removal of total fallout activity, because the bulk of the activity was associated with suspended matter before impoundment. Removal of much of the suspended fallout activity can be accomplished by conventional water treatment processes (coagulation and rapid sand filtration). On the other hand, these processes are quite ineffective for the removal of filtrate (dissolved) radioactivity.

Radioactive runoff was a small fraction of the total radioactive fallout. Most of the 1958 fallout on the highly developed agricultural area of the lower Missouri River and central Mississippi River occurred during the crop-growing season. These facts and the correlation of fallout, radioactive runoff, and strontium-90 in milk indicate that foliar deposition may be an important contributor to the total radiation exposure of man, which, to be evaluated, requires closely coordinated studies of natural and artificial exposures to radioactivity from external sources and from inhalation and ingestion. Ingestion of radioactivity may come from drinking water and, more particularly, although not included in these studies, food that may be produced in areas far removed from the point of consumption.

The method of study applied to the radioactivity of the Mississippi and Missouri River basins is suggested as a model technique for determining the meaning and significance of radioactive contamination in other drainage basins.

**Acknowledgment**

The authors express their appreciation to Richard S. Green, Chief, Basic Data and Economics Sec., Water Pollution Control Div., and to Ralph Palange, Asst. Chief, and Stephen Megregrian, In Charge, Lab. Services, Basic Data Unit, Water Supply & Water Pollution Control Program, Robert A. Taft San. Eng. Center, Cincinnati, Ohio, for the data used in this article, which are a small part of the comprehensive report on the National Water Quality Network (*3*). Grateful acknowledgment is made to personnel from local agencies, for their assistance in obtaining samples; US Army Corps of Engineers and USGS, for supplying hydrologic data; USPHS regional office, for supplying other technical information; and the laboratory staff of Radiological Health Research Activities, Taft Center, for their general assistance.

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The authors are indebted to Conrad P. Straub, Chief, Radiological Health Research Activities Program, Div. of Radiological Health, Taft Center, for technical advice and editorial assistance.

TABLE 11

*Radionuclides and Mean Values for Radioactivity in Milk From Cincinnati and St. Louis Areas* *

| Month | Radioactivity—$\mu\mu c/l$† | | | | | | Rainout $m\mu c/sq\ m$ |
|---|---|---|---|---|---|---|---|
| | $I^{131}$ (8 days) | $Ba^{140}$ (12.5 days) | $Sr^{89}$ (54 days) | $Sr^{90}$ (28 yr) | $Cs^{137}$ (30 yr) | Total | |
| Mar. | 0 | 3 | 12 | 7 | 58 | 80 | 43 |
| Apr. | 65 | 25 | 24 | 9.3 | 55 | 178 | 139 |
| May | 0 | 15 | 88 | 9.3 | 72 | 184 | 105 |
| Jun. | 0 | 40 | 114 | 13.2 | 87 | 254 | 252 |
| Jul. | 365 | 170 | 250 | 15.8 | 128 | 929 | 562 |
| Aug. | 51 | 98 | 180 | 10.8 | 96 | 436 | 127 |
| Sep. | 12 | 30 | 190 | 12.4 | 81 | 325 | 59 |

* 1958 data. All data, except those in the "total" column, are from USPHS publication, No. 3055 (Mar. 1959).

† Half-life values of radionuclides are shown in parentheses.

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## Discussion

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There is a great need for fundamental data on radioactivity in surface waters of the United States. Numerous water utilities and local health agencies are collecting information on radioactivity in water, but the concerted program known as the National Water Quality Network of USPHS will establish the long-term trends that might otherwise be difficult or impossible to determine. These data will be useful for evaluating the extent of surface water pollution caused by the dispersal of radioactive wastes; for determining the fate of radioactive fallout or rainout; and for developing a realistic approach to water quality standards and treatment processes for the removal of radioactive products from surface waters.

### Southern California Studies

The Metropolitan Water District of Southern California became concerned about the possibility of low-level radioactive contamination of its Colorado River water supply when the AEC initiated its nuclear-weapons test program at the Nevada proving grounds in January 1951. Prior to the first tests, 53 soil-sampling stations were established in areas adjacent to the Colorado River watershed and Lake Mead with the cooperation of the Los Angeles Department of Water and Power and the California Disaster Office. Reference soil and water sam-

ples were collected for background information in order to estimate the extent of environmental contamination after the weapons-testing activities were completed. A regular program of assaying radioactivity in Colorado River water from Lake Mead, Lake Havasu, and along the route of the Colorado River aqueduct was initiated at the softening and filtration plant laboratories at La Verne, Calif. Certain data from the program are pertinent to this discussion.

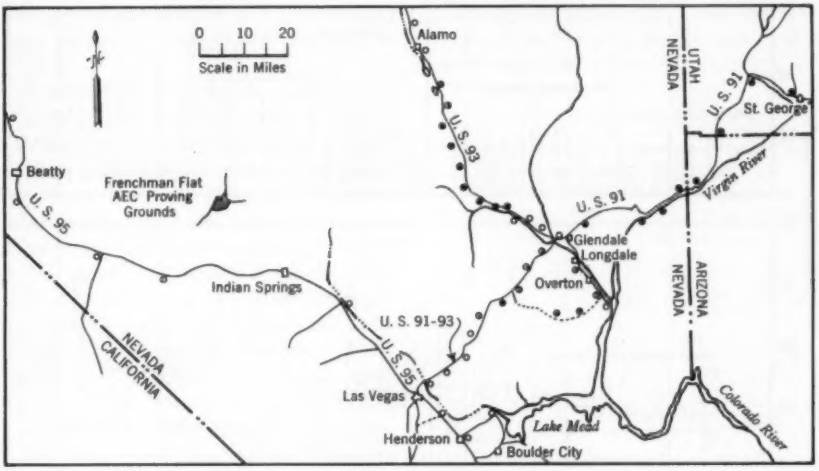


**Fig. 7. Radiologic Survey of Lake Mead Watershed Area**

*Key: Open circles represent field readings of 0.01–0.049 mr/hr; half-filled circles, 0.50–0.49 mr/hr; filled circles, 0.50–2.0 mr/hr. This survey was made on Jul. 1 and 2, 1953, about 60 days after the AEC test series*

*Residual Radioactivity*

Field radiologic surveys made in September 1951 and in January 1952 showed no evidence of fallout in the Lake Mead area, despite the widespread detection of above-normal activity in California after atomic bombs were detonated from Oct. 28 to Nov. 5, 1951. The radioactivity was apparently dispersed widely across the United States without appreciable local fallout. By contrast, a resurvey made on Jul. 1 and 2, 1953—almost 60 days after the spring test series of 1953—showed residual activity at some points amounting to more than 100 times the normal soil activity observed in earlier surveys. Figure 7 shows that the residual radioactivity lay principally to the north of Lake Mead, in the Muddy River and Virgin River watersheds. Near the Lake Mead shore line, much lower activities were detected. In May 1955, fresh fission products caused areas to the east of the proving grounds to become 230–760 times more radioactive than normal. Decay measurements indicated that residual activity at some stations was deposited 2 years earlier.

After the suspension of nuclear-weapons tests, another survey was conducted in January 1959. From these data, the average and maximum increase of beta activity remaining in the surface soil was calculated (Table 12). The highest level of residual beta activity amounted to 1,309 mμc/sq m, or 25 times the original. the Colorado River Aqueduct has increased 50 per cent or less during the recent, intensive nuclear-test period.

### *Gross Radioactivity*

Gross alpha and gross beta radioactivity measurements were made monthly on 2-qt grab samples from Lake Mead and Lake Havasu. Depth

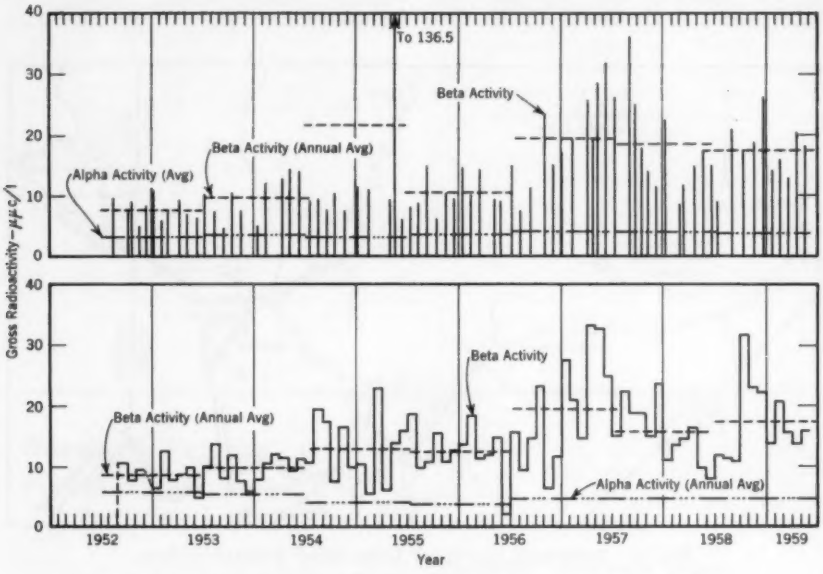


**Fig. 8. Gross Radioactivity of Colorado River Aqueduct Water**

*The illustration on top shows the gross radioactivity in grab samples taken at Lake Havasu, near the intake pumping plant. The bottom illustration presents data on monthly composite samples of the influent to the softening and filtration plant at La Verne, Calif.*

It may be noted that residual fallout was lowest to the west and south of the Nevada proving grounds—that is, in the direction of California, where local monitoring activities and public notice of fallout incidents have caused great concern about exposing large population centers to high local fallout. The radioactivity in soils adjacent to

samples were taken at Lake Mead, but surface water only was collected at Lake Havasu. Similar radioactivity assays were made on monthly composite samples of phase influent and effluent waters taken daily at La Verne. The influent water was the same as that taken from Lake Mathews at depths of 15–30 ft. Lake

Mathews is the district's terminal storage reservoir with a capacity of 107,000 acre-ft.

Data on the gross radioactivity of Colorado River water at Lake Havasu and the plant influent at La Verne are shown in Fig. 8. Very little change in gross beta activity was observed until late in 1954. The major increase occurred during Jul. 1, 1956, to Jun. 30, 1957, the 12-month period for which annual averages were calculated. No significant change in alpha activity has occurred because of radioactive fallout.

The more consistent pattern of changes obtained by combining daily samples into a single monthly sample for radioanalysis is readily apparent as one notes the distortion of the annual average at Lake Havasu in 1955. This distortion is the result of a single grab sample having abnormally high activity (136.5 $\mu\mu$c/l). The monitoring program at Lake Havasu and Lake Mead is designed to provide a forewarning of changes in water quality; therefore, a more intensive sampling procedure has not seemed necessary. The leveling off of total beta activity in recent months has given rise to hopes that suspension of nuclear-weapons tests by the major military powers may lead to a reversal of the upward trend.

Continued rainout of long-lived fission products, particularly strontium-90, accumulated in the stratosphere may, however, constitute long-term problems as suggested by Kramer and colleagues (*1*). Total beta rainout has remained high during the period from January to June 1959, amounting to 284 m$\mu$c/sq m at La Verne, only slightly less than the total rainout of 327 m$\mu$c/sq m from February to June 1958. Measurements of radioactive strontium in rainfall occurring on Feb. 12, 16, and 17, 1959, about 3 months after the suspension of nuclear tests, showed that strontium-89 and strontium-90 comprised 4.0–4.67 per cent of the total initial radioactivity present. Thus, if rainout increased the total beta activity in a surface water to 100 $\mu\mu$c/l, it would add less than 5 $\mu\mu$c/l of radioactive strontium, an amount difficult to detect by radiochemical separation methods.

The gross activity of some samples reported in Setter's article was sufficiently high to allow for a study of the distribution of radionuclides by the special separation techniques being developed at the Taft Center. Further interesting reports can therefore be anticipated from this program.

TABLE 12

*Residual Radioactive Fallout and Rainout in Surface Soils in the Vicinity of the Nevada Proving Grounds—1959*

| Location of Surface Soils* | No. of Stations | Beta Activity | | |
|---|---|---|---|---|
| | | Avg m$\mu$c/sq m | Max. m$\mu$c/sq m | Max. Increase % |
| East | 29 | 114.2 | 1,309.0 | 2,510 |
| North | 11 | 75.2 | 202.5 | 316 |
| West | 4 | 88.5 | 101.7 | 208 |
| South | 5 | 29.7 | 51.4 | 86 |
| Along Colorado River Aqueduct system | 6 | 15.9 | 25.9 | 50 |

* Given as the direction away from the Nevada proving grounds.

Surveillance of air activity can be most helpful in the detection of dry radioactive fallout that might affect surface water supplies. The infrequency of rainfall in arid climates has led the district to institute, at the La Verne treatment plant, a program of air sampling for the detection of airborne radioactivity. Particulate mat-

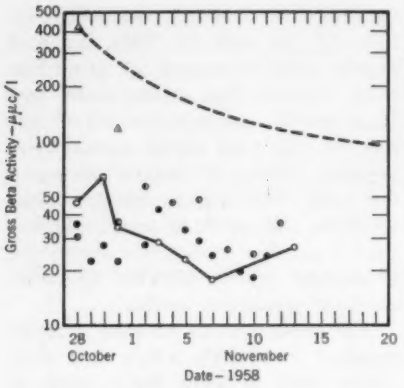


**Fig. 9. Gross Beta Radioactivity in Water Samples Taken After the October 1958 Fallout**

*Key: Triangles and open circles represent Garvey Reservoir surface water and effluent, respectively; half-filled circles, Palos Verdes Reservoir surface water; filled circles, La Verne treatment plant effluent. The dashed curve represents the decay of the Garvey Reservoir surface water sample taken on Oct. 28, 1958.*

ter is collected on filter paper passing air at the rate of 1 cu ft/min for 24 or 48 hr. Data on frequency of occurrence of different beta activity levels in air samples taken during 1958 and 1959, before and after the October 1958 fallout incident, are presented in Table 13. Activities less than 5 μμc/cu m are considered normal; values greater than 10 μμc/cu m are definitely indicative of abnormal radioactivity in the atmosphere of Southern California. Those values between 5 and 10 μμc/cu m may contain a small amount of extraneous radioactivity, apart from natural radioactive elements on industrial pollutant dusts. The greater number of samples containing 5–10 μμc/cu m obtained since Oct. 22, 1958, indicates that low-level dry fallout persisted for several months after the high fallout indicated by about 28 samples taken in October and November 1958. During this period of high fallout, there were only four rainstorms, producing a negligible amount of precipitation (a total of 0.54 in.). Without the information on dry, airborne radioactive contamination, the fallout incident of October 1958 might have gone undetected. When the first sign of increased airborne radioactivity was noted, however, a stepped-up sampling program was initiated at the district's distribution system reservoirs in which treated water was stored. These reservoirs are uncovered because of their large size. Garvey Reservoir has a storage capacity of 1,500 acre-ft; Palos Verdes, 1,000 acre-ft.

The gross beta activity in two surface samples taken at Garvey Reservoir on October 28 and 31 was higher than the maximum permissible concentration of 100 μμc/l, but the effluent water was much lower in activity. This was definitely the result of dilution and sedimentation, because decay alone, as shown in Fig. 9, could not account for the rapid lowering of activity. For several days, the beta activity remained greater at Garvey and

TABLE 13

*Frequency of Occurrence of Different Beta Activities in Air Samples, 1958–1959*

| Range of Beta Activity μμc/cu m | Air Collection Period | | | |
|---|---|---|---|---|
| | Feb. 22, 1958–Oct. 21, 1958 | | Oct. 22, 1958–Jun. 8, 1959 | |
| | No. of Samples | Percentage of Total | No. of Samples | Percentage of Total |
| 0–5 | 175 | 87.0 | 54 | 35.1 |
| 5–10 | 20 | 10.0 | 72 | 46.8 |
| 10–20 | 3 | 1.5 | 11 | 7.1 |
| 20+ | 3 | 1.5 | 17 | 11.0 |
| *Total* | 201 | 100.0 | 154 | 100.0 |

Palos Verdes reservoirs than in the water entering the reservoirs from the treatment plant. Then the difference in activity between influent and effluent waters became insignificant.

*Solubility of Fission Products*

The low solubility of radioactive fission products from nuclear explosions has been a favorable factor in reducing the contamination of Southern California surface water supplies. Setter has mentioned the important role of sedimentation for the removal of radioactivity from impounded waters. It is not easy to observe such changes. The data obtained from depth samples taken at Lake Mead (Table 14) indicate that sedimentation occurs in reservoirs, especially if the size of suspended matter is relatively large.

The low solubility of fission products also favors their removal by normal water treatment processes. The La Verne softening and filtration plant was operating without coagulants during the October 1958 fallout period, and the removal efficiency for dry fallout activity varied from 18 to 75 per cent even under these conditions. Reports by others (*2*) that removal efficiency improves as the radioactive load increases have been confirmed. In the event that the concentration of radioactive materials in Colorado River water should warrant special treatment, plant operating procedures could be modified to effect more complete removal of radionuclides from the plant effluent. Laboratory tests show that continuous use of lime, coagulant aids, and activated silica, followed by filtration and complete cation exchange, will remove 90–98 per cent of mixed-fission product activity from the water.

TABLE 14

*Changes in Gross Beta Radioactivity With Depth in Lake Mead, Indicating Removal by Sedimentation*

| Date | Radioactivity—μμc/l | | | |
|---|---|---|---|---|
| | 25 ft | 125 ft | 275 ft | 325 ft |
| Apr. 30, 1952 | 3.3 | 7.9 | | 22.6 |
| Apr. 29, 1955 | 5.7 | 9.9 | 22.0 | 23.2 |
| Apr. 30, 1956 | 6.3 | 15.7 | 22.2 | |
| Dec. 28, 1956 | 17.5 | | 38.2 | |

## Conclusion

For adequate protection of a surface water supply from radioactive pollution, the monitoring of airborne particulate matter and rainfall is just as important as the examination of water itself. The surveillance network reported by Setter is making a valuable contribution to the knowledge of the distribution and fate of radioactive materials. Utility operators, however, must not abdicate their responsibilities for instituting programs for local inspection and control of water quality with respect to radioactivity.

## Acknowledgment

Appreciation is expressed to William R. Ree Jr., Los Angeles Department of Water and Power, for his assistance in making the 1955 and 1959 field radiologic surveys in Nevada. The assistance of H. B. Page, H. W. Sundberg, and G. D. Mayhew, all of the Metropolitan Water District of Southern California laboratory staff, in helping with the radioanalysis of air, soil, and water samples, is gratefully acknowledged.

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Shortly after World War II, the management of the Chicago water utility system recognized that harmful radioactive contamination of its Lake Michigan water supply might occur in the future from wastes from nuclear power plants; sewage wastes containing isotopes discharged from hospitals and industrial plants; enemy action; or fallout from nuclear-bomb tests. Studies were started in 1949 to develop basic data on the natural background levels of radioactivity in uncontaminated Lake Michigan water. The purpose of these studies was to allow for better detection of even the slightest increase in radioactive contamination. Tests were also started to determine the efficiency of conventional filtration processes in decontaminating radioactive water.

The Chicago water system probably was among the first to institute routine monitoring of a lake water supply when it started these tests in 1950. The program has been continued to the present time, with modifications and expansions as improvements of technique and developments in instrumentation have occurred.

The radiologic laboratory at the South District Filtration Plant is equipped with two internal proportional counters and a conventional binary scaler. The techniques used in the laboratory are described fully in a previous article (*1*). This discussion is concerned primarily with summarized data regarding monthly average gross radioactivity in the raw lake water and in the filtered outlet water of the South District Filtration Plant for the years 1956–1958, inclusive, and for the first 5 months of 1959, shown in Tables 15 and 16. Also shown in the tables are the monthly averages of the percentage of radioactivity removed by filtration.

## Lake Michigan Studies

During the period covered, the greatest concentration of radioactivity in the lake water was detected during the summer months of 1957 and during March–May 1959. The annual average gross radioactivity of the raw lake water was 6.65 $\mu\mu$c/l in 1956, 12.22 $\mu\mu$c/l in 1957, 7.46 $\mu\mu$c/l in 1958, and 14.10 $\mu\mu$c/l for the first 5 months of 1959 (Table 15). The increases in radioactivity generally occurred when

TABLE 15

*Annual Gross Radioactivity, Lake Michigan*

| Year | Radioactivity—$\mu\mu$c/l | | | | | | Radioactivity Removal—% | | |
|---|---|---|---|---|---|---|---|---|---|
| | Raw Water | | | Outlet Water | | | Avg | Max. | Min. |
| | Avg | Max. | Min. | Avg | Max. | Min. | | | |
| 1956 | 6.65 | 23.97 | 2.48 | 3.24 | 10.16 | 1.04 | 51.3 | 88.1 | 1.21 |
| 1957 | 12.22 | 42.03 | 3.26 | 8.26 | 25.31 | 2.43 | 32.4 | 53.1 | −4.0 |
| 1958 | 7.46 | 12.95 | 2.04 | 4.51 | 8.56 | 0.96 | 39.1 | 63.9 | 24.0 |
| 1959* | 14.10 | 19.46 | 7.34 | 7.08 | 10.17 | 4.08 | 49.8 | 57.3 | 41.0 |

* Values for 1959 are for the first 5 months of the year.

TABLE 16

*Average Monthly Gross Radioactivity, Lake Michigan*

| Month | 1956 | | | 1957 | | | 1958 | | | 1959 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Radioactivity $\mu\mu c/l$ | | Radioactivity Removed % | Radioactivity $\mu\mu c/l$ | | Radioactivity Removed % | Radioactivity $\mu\mu c/l$ | | Radioactivity Removed % | Radioactivity $\mu\mu c/l$ | | Radioactivity Removed % |
| | Raw Water | Outlet Water | | Raw Water | Outlet Water | | Raw Water | Outlet Water | | Raw Water | Outlet Water | |
| Jan. | 3.19 | 2.00 | 37.3 | 3.52 | 2.43 | 30.9 | 3.93 | 1.90 | 51.7 | 7.34 | 4.08 | 44.4 |
| Feb. | 6.12 | 1.80 | 70.6 | 7.43 | 3.48 | 53.1 | 3.96 | 1.43 | 63.9 | 9.65 | 5.26 | 45.5 |
| Mar. | 3.74 | 1.08 | 71.1 | 4.14 | 3.17 | 23.5 | 2.04 | 0.96 | 52.8 | 16.54 | 7.45 | 55.0 |
| Apr. | 2.48 | 2.45 | 1.21 | 3.26 | 3.40 | −4.0 | 5.58 | 2.70 | 51.6 | 19.46 | 8.30 | 57.3 |
| May | 5.59 | 3.30 | 41.0 | 3.57 | 3.27 | 8.3 | 7.19 | 3.67 | 34.2 | 17.25 | 10.17 | 41.0 |
| Jun. | 3.98 | 2.05 | 44.5 | 4.71 | 3.25 | 31.1 | 11.78 | 7.81 | 33.7 | | | |
| Jul. | 4.99 | 4.03 | 19.2 | 42.03 | 25.31 | 40.0 | 12.95 | 8.56 | 33.9 | | | |
| Aug. | 23.97 | 10.16 | 57.6 | 23.00 | 15.92 | 30.8 | 9.72 | 7.07 | 27.3 | | | |
| Sep. | 6.12 | 4.26 | 30.4 | 13.28 | 10.46 | 21.3 | 7.03 | 5.34 | 24.0 | | | |
| Oct. | 5.05 | 3.91 | 22.6 | 7.02 | 6.53 | 6.9 | 8.93 | 6.04 | 32.4 | | | |
| Nov. | 9.29 | 2.37 | 74.5 | 4.78 | 3.86 | 19.4 | 8.97 | 5.28 | 41.1 | | | |
| Dec. | 8.72 | 1.04 | 88.1 | 5.48 | 3.06 | 44.2 | 7.18 | 3.44 | 52.1 | | | |
| Avg | 6.65 | 3.24 | 51.3 | 12.22 | 8.26 | 32.4 | 7.46 | 4.54 | 39.1 | 14.10 | 7.08 | 49.8 |
| Max. | 23.97 | 10.16 | 88.1 | 42.03 | 25.31 | 53.1 | 12.95 | 8.56 | 63.9 | 19.46 | 10.17 | 57.3 |
| Min. | 2.48 | 1.04 | 1.21 | 3.26 | 2.43 | −4.0 | 2.04 | 0.96 | 24.0 | 7.34 | 4.08 | 41.0 |

nuclear-bomb tests were conducted in various parts of the world. The average removal of radioactivity, with the routine filtration treatment at the South District Filtration Plant, was approximately 40 per cent.

When high radioactive fallout was detected after the 1951 nuclear-bomb tests began, rainfall samples were collected at five widely separated rain gages operated by the water department. The results of tests for radioactivity in rainfall samples, which are not presented in this discussion, roughly parallel the increases and decreases in activity found in the lake water. Recent tests show that the apparent half-life of radioactivity in rain water has increased from approximately 6 days in October 1958 to approximately 3 months in March and April 1959. Samples of raw water, filtered through membrane filters, show about the same percentage of removal of radioactivity as occurred with the conventional filtration process, indicating that the removal of activity is limited to particulate material.

When compared with the proposed maximum permissible level for unidentified gross activity (10 $\mu\mu c/l$ in water for lifetime use), the average monthly gross radioactivity exceeded this level during 1 month in 1956, 3 months in 1957, 2 months in 1958, and 3 of the first 5 months in 1959 (Table 16). The significance of these results is not thoroughly understood.

## Acknowledgment

Tests for radioactivity are conducted at the South District Filtration Plant by Alfred M. Tenny, Water Chemist III, and by Robert W. Schmidt, Water Chemist IV. The Department of Water and Sewers is directed by Commissioner James W. Jardine. The Bureau of Water is directed by W. W. DeBerard, Deputy Commissioner for Water and Chief Water Engineer. The Water Purification Division is directed by John R. Baylis.

## Reference

1. VAUGHN, J. C., ET AL. Studies of Radioactivity in the Chicago Water Supply. *Jour. AWWA,* **50**:581 (May 1958).

***Harry P. Kramer***

*Chief, Training Program, Robert A. Taft San. Eng. Center, Cincinnati, Ohio.*

In general, radioactive contamination of surface waters is principally a result of fallout from tests of nuclear weapons and natural radioactivity. The magnitude of contamination differs markedly with time and location. Because of its public health significance, a continuous appraisal of contamination levels affecting large population groups is necessary. In the article being discussed, water-monitoring information on a nationwide basis has been reported for the first time, and the behavior of radioactive materials in the environment has been considered. One must understand these behavior patterns in order to evaluate the various ways that man becomes exposed to radioactivity and to determine where control measures can best be applied.

**Health Hazards**

Fallout debris may gain entrance to the human body through many avenues. Important among them is the water supply, for about 80–90 per cent of total radioactive fallout reaching the earth accompanies rain or snow. Following deposition on the earth's surface, however, only a small fraction of radioactive material remains in runoff carried into streams. The authors have reported that, on the average, only about 1 per cent of the total fallout activity reaches surface waters, closely supporting the data reported by Thomas (*1*) on watersheds in the northeastern part of the United States.

The amount of radioactive fallout in surface waters, though only a small fraction of the total fallout, is nonetheless large when compared with the quantities of radioactive industrial wastes being discharged into these same waters. As the authors indicate, the health hazard associated with drinking these waters is lessened by certain factors. For example, period of flow reduces the radioactivity significantly, as most of the radionuclides in fresh fallout have comparatively short half-lives. Obviously, this factor is most important during periods of weapons testing. Where waters are of moderate or high turbidity, conventional water treatment procedures may remove a major portion of the radioactive materials. The correlation of radioactivity concentrations with concentrations of suspended solids, as shown by the authors, is of interest. This correlation could be the result of sorption of radionuclides on suspended material or because of the insolubility of fallout particles in water. The authors note that if it becomes necessary to reduce the amount of radioactivity in drinking water, the use of waters during peak flow periods should preferably be avoided. Although this may reduce the gross level of radioactivity in the treated water, a simultaneous reduction of those radionuclides contributing the major health hazard may or may not be effected.

The principal purpose of a nationwide monitoring study of this type is to keep a surveillance over public health problems associated with the use of surface waters for drinking. Data on radioactivity in water must of necessity be correlated with man's intake of radioactivity from other sources, such as food and air, as well as with his exposure to external radiation. A true assessment may require knowledge of the specific nuclide content in each of these sources, because the maximum permissible concentra-

tions of nuclides differ. At present, the low level of most surface water contamination does not warrant specific nuclide determinations on a routine basis. Rather, it is anticipated that measurements of gross alpha and beta radioactivities will show any significant trends or changes that might necessitate a more detailed appraisal of the health hazard.

### Radioactivity in Soil

As discussed earlier, nearly all (about 99 per cent) of the radioactivity deposited by fallout remains on soil and vegetation and is not carried, directly at least, by runoff into streams. Limited studies on radioactivity levels in vegetation, milk, and other foodstuffs have demonstrated that some of the contamination is the result of foliar deposition. Eventually, a major portion of the deposited long-lived radioactivity will become incorporated in the soil where it may gradually be leached into ground or surface waters. The resulting health problems may be of far greater long-term significance than the problem resulting from immediate runoff into streams. To evaluate this problem, intensive radioactivity balance studies should be undertaken on typical agricultural and watershed areas. It must be emphasized that the behavior pattern of fallout radioactivity in soil is much less understood than the behavior patterns presented by the authors for radioactivity in water. Yet, the behavior of the former is of much importance to an understanding of the overall problem because of the interplay of soil and water.

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1. THOMAS, H. A. The Public Health Implications of Radioactive Fallout in Water Supplies. *Am. J. Public Health*, **46**:10, 1266 (1956).

# Federal Program for Collection of Basic Data on Water Use

**Walter L. Picton**

*A contribution to the Journal by Walter L. Picton, Director, Water & Sewerage Industry & Utilities Div., Business & Defense Services Administration, Dept. of Commerce, Washington, D.C.*

RELIABLE basic data on all types of water use have long been needed by the nation's industries and water resources development planners. Since 1948 the need for coordinated collection, assembly, and publication of such data has been recognized, and interested federal agencies have given their support and cooperation to the development of such a program. The author has long been an advocate of such planning.

## USGS Programs

Some marked progress has been made, and, in the Water Resources Division of USGS, four new programs have been initiated:

1. Since 1950, USGS has made, at 5-year intervals, an extensive survey of the United States to produce estimates of water use by category of use and by state.

2. Since 1950, USGS has made surveys in the major metropolitan areas of the United States, including areas of probable future expansion. The surveys include data on water utilization by all users in the area, ground and surface supplies, the present extent of development of water resources, and the potential development for future growth. About 30 such areas have already been covered, and 25 more are now being surveyed. The program will eventually include about 100 such areas. Results are published in a series of circulars.

3. Since 1950 USGS has made surveys of selected industries in order to ascertain the volume and manner of water use in those industries. The detailed information, obtained primarily for the benefit of national security, is kept confidential. With the permission of the industrial plants visited, however, a summary of this information, in such a form as not to reveal the details of any plant's operations, is published in a series of USGS water supply papers. About six of these studies have been published and eight or ten more are in process. The program will probably include 30–40 studies.

4. In the fall of 1953, USGS made a survey of the nation to ascertain the number of water utilities with shortages or impending shortages serious enough to require restrictions on water use. It was intended that this type of survey be made in future years whenever widespread droughts occurred. Pressure of other work and shortage of funds prevented repetition of this survey in 1956 and 1957, but it is hoped that the survey can be repeated

if there should be another widespread drought.

**Progress During 1953–55**

During 1953–55 the following was accomplished:

1. The 1953 Annual Survey of Manufactures collected data on water use from those manufacturing plants using 20 mil gal or more in the calendar year 1953. The data were published in a special bulletin by the Bureal of Census entitled "Water Use in Manufacturing," which presents, by industries, water use regions, and states, the volume of fresh and brackish water used, the percentage represented by brackish water, the percentage of fresh water purchased and the percentages of self-supplied water obtained from surface and ground sources, and the volume of recirculated water.

2. The 1954 Census of Manufactures collected data on water in manufacturing establishments using 20 mil gal or more in the calendar year 1954. The data were published in a bulletin entitled "Industrial Water Use." In addition to the kinds of data presented in the 1953 survey, this publication includes, by industries, water use regions, and selected industrialized counties, the number of establishments using less than 20 mil gal. For those using more than 20 mil gal, data are presented on the volume of water treated; water used for processing, cooling, air conditioning, boiler feed, and other uses; number of establishments recirculating water; estimated water requirement if no water were recirculated; volume discharged; and volume treated prior to discharge.

3. The 1954 Census of Mineral Industries collected data on water use which were published in a bulletin entitled "Energy, Water, and Selected Supplies." The bulletin presented, by industries and by states, data on water intake and water discharge, volumes purchased from public water utilities, self-supplied water from ground and surface sources, the volume of use in mines, and volumes of mine water drained and discharged.

4. In 1954 the Federal Power Commission made a survey of water use in the steam generation of power by electric utilities. Data were published presenting, by states, water use, the total intake of fresh and brackish water, volumes obtained from surface sources or wells, total volume discharged, total volume evaporated, volume recirculated, and probable requirements if there had been no recirculation.

5. At the close of 1954, USPHS instituted a program of making periodic inventories of the major public water supplies (serving 25,000 population or more), presenting the population served, average daily water production, maximum day and maximum month demand, the capacities of the principal facilities in the system, and other data. Such inventories were also made for the close of the years 1955–57.

6. In 1954–55, the Department of Defense collected data from the military installations in the United States. Data include information on self-supplied and purchased water and the capacities of the key facilities for production and treatment. Although not published, the data may be had on request by any individual or organization having a recognized need for the information.

7. Similar data are available on sewerage.

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7. Similar data are available on sewerage.

Some sources felt that questions on water use should be included in the 1955–57 annual surveys of manufactures, but this was not done.

**Recent Developments**

More recent developments in data collection include the following:

1. The President appointed the Interagency Water Resources Committee composed of six Cabinet members to review, consider, and make recommendations on water resources policy and to review the studies and planning of the various interagency river basin or regional committees.

2. Under the interagency committee, the Hydrology Subcommittee has been established to review the federal program for assembly of basic information on rainfall, runoff, streamflow, and natural availability of surface and ground water in the United States and make necessary recommendations.

3. Under the Hydrology Subcommittee a work group on water use data has been established and has just completed a survey of the collection of basic water use data by all federal agencies and is reporting on the inventory to the Hydrology Subcommittee. It is hoped that the inventory of available data will be published as one of a series of bulletins of the subcommittee. It is anticipated that there will be an evaluation of the federal collection of basic data on water use, including recommendations for rectification of any deficiencies.

4. For 1958 USPHS made a comprehensive survey of the approximately 18,000 public water utilities and obtained primary data such as the form of ownership, population served, average daily production, source of water supply, and type of treatment.

5. In 1958 USPHS completed an inventory of the nation's sewerage utilities and published a pamphlet for each state, presenting the population served, type of treatment, place of discharge, and other pertinent information, for nearly 13,000 sewerage utilities and a considerable number of industrial plants discharging liquid wastes.

6. As a supplement to the 1954 Census of Agriculture, a survey was made in 1955 covering irrigation in the 28 eastern humid states. The data collected were published in a special report entitled "Irrigation in Humid Areas." This presents for the years 1954 and 1955 the number of farms irrigated, the number of acres irrigated, frequency of irrigation, type of facilities (pumps, dams, and reservoirs), cost of construction and equipment, and other data.

**Recommendations for 1959–60**

For the years 1959–60, federal and industrial task groups have recommended that:

1. Water use data be collected in the 1959 Census of Irrigation, covering the seventeen western states, Arkansas, Louisiana, and Florida, and that data be collected in the 28 eastern humid states in the 1959 Census of Agriculture

2. As an integral part of the 1958 Census of Manufactures and Census of Mineral Industries, water use data be collected in the calendar year 1959 on water use by these industries (The data will be presented with some amplification as compared with the 1954 censuses, in accordance with recommendations of a federal task group and an industry task group from the water industry.)

3. The 1960 Census of Housing collect data on rural housing, the source of water supply, and the method of sewage disposal

4. The Federal Power Commission make another survey covering the calendar year 1959 to obtain data on water use in the steam generation of power by electric utilities, which will include additional data such as the mean temperature differential between the intake and the discharge

5. The Federal Power Commission also assemble data and estimates for the year 1959 of the volume of water used in the generation of hydroelectric power by electric utilities

6. USPHS again collect data on the major public water supplies (serving 25,000 people or more) as of the close of the calendar year 1959

7. USPHS collect similar data on the major public sewerage utilities (serving 25,000 people or more) as of the close of the calendar year 1959

8. The Department of Defense again survey the water supply and sewerage requirements and facilities as of the fiscal year ending Jun. 3, 1960.

**Future Surveys**

As part of a tentative program for later years, it is planned that:

1. The Water Resources Division of USGS repeat its national survey of water use at 5-year intervals

2. The Water Resources Division of USGS continue its program of the surveys of the water resources of the selected metropolitan areas

3. The Water Resources Division of the USGS continue its program of the survey of water use of selected industries and products, making the information available to the public, when possible

4. The Water Resources Division of the USGS make every effort to make surveys of water shortages experienced by public water utilities when drought conditions justify such surveys

5. USPHS continue annual inventories of the major public water supplies and, at 5-year intervals, complete inventories of all public water systems

6. USPHS continue annual inventories of the major public sewerage systems, at 5-year intervals, complete inventories of all public sewerage systems

7. The Federal Power Commission repeat the survey of electric utilities at 5-year intervals

8. The next Census of Manufactures (probably 1963) repeat the census of water use with such revisions and amplifications as are deemed advisable

9. The intervening annual surveys of manufactures (1960–63) be used as vehicles to obtain such additional data on water use in manufacturing as may be deemed of special value for industrial and water use planning

10. The next Census of Mineral Industries (probably 1963) repeat the census of water use, with such revisions as may be deemed advisable

11. Such amplification or additional data as may be determined advisable be included in the next Census of Irrigation, Census of Agriculture, and Census of Housing.

**Publication of 1954 Data**

In accordance with past recommendations from the Business and Defense Services Administration the following special extracts of data from the 1954 censuses are being made and will be available this year:

1. Census of Mineral Industries—a retabulation of water use data by the

mineral industries classified by water use regions

2. Census of Manufactures—a retabulation of data on water use by those manufacturing plants using 20 mil gal or more in the calendar year 1954 in summary by states

3. Census of Manufactures and Mineral Industries and a Federal Power Commission survey of water use by steam electric utilities—an assembly and tabulation by water use regions

4. Census of Manufactures—a tabulation of water use by industries by those establishments which generate steam electric power

5. Census of Manufactures—data on water use by establishments using 20 mil gal or more in 1954, and a tabulation, by industries, of establishments practicing recirculation of water, indicating also which of them generate their own electric power

6. From No. 4 and No. 5, above—tabulations of water use by states and by water use regions.

## Conclusion

It is believed that water use data collected in the interim program, as made available in published form, will be of high value both to federal and to nonfederal water resources planners, to state and local governments, and to business and industry. At some later date the program can be revised and amplified as a result of the studies and evaluations made by the work group under the hydrology subcommittee and of recommendations of the President's interagency water resources committee.

# Uses of Budgets and Cost Accounting Systems

## Joint Discussion

*A joint discussion presented on Jul. 16, 1959, at the Annual Conference, San Francisco, Calif.*


### J. Philip Dieter

*Controller, East Bay Munic. Utility Dist., Oakland, Calif.*


AS an organization grows, its management must delegate more authority to subordinate executives. This is done, of course, because management cannot organize and check all the details necessary for a company's day-to-day operations. At the same time, some type of control is needed to insure that executives conform to approved general policies; that they act only on matters within their jurisdiction, as prescribed by the company's organizational structure; and that they are held responsible for their actions. By planning and controlling the organization's budget, management has an effective tool for controlling expenditures and gaging the performance of subordinates.

### Budgets

An organization budget is a financial statement of estimated income and expenses for a period of time. It is essential to the establishment of an organization's goal. It attempts to set up in advance a business plan of action supported by figures of all the essential factors, such as: revenues; purchases; production expenses; operation, maintenance, and administrative expenses; depreciation; and interest. Budgetary estimates are based partly on past experience and partly on expected conditions.

Almost any future program for a business enterprise is better than none at all, and most intelligent plans depend to some extent on a preliminary forecast of conditions. As the ultimate aim of top management is to produce a profit, a budget forecast of estimated profit is valuable for highlighting the various factors that need to be kept under control in order to realize the planned-for objective. To plan the profit, however, is only half the battle of business. The other half is actually to produce the profit, which involves the coordination of actual operating conditions with the budget forecast.

Among the many kinds of budgets are the sales, inventory, and departmental expense budgets. Other types of budgets also serve as tools for enlightened management; two of the most important of these are the construction budget and the cash budget.

Progressive utility officials are aware of the importance of replacing inefficient plant with the latest improvements, especially when studies show that increased investment can reduce operating costs or increase profits. The budget, adjusted for noncash expenses, provides information about the availability of funds for new investments and when these investments should be made. If the budget shows that the utility will not have

the assets to make new investments, there is still time to do something about it during this advance stage of planning. The chief executive can adopt measures to minimize losses and increase revenues by introducing forced economies on some departments and by increasing the company's advertising allotment. The point to be emphasized is that losses or insufficient profits already made must be accepted, but if conditions are foreseen, it may be possible to do something about them. Thus, budgets are useful both in prosperous and difficult times.

*Performance of Personnel*

As mentioned before, a budget also serves as a standard against which the performance of personnel can be judged. It predicts the prospective activities of company executives, who must have the ability to help make and operate within the budgets for their respective departments. With the knowledge that he is operating satisfactorily within his budget, an executive can develop a sense of well-being and confidence. At the same time, a certain amount of freedom to exceed budgets must be allowed. A business can usually afford to let an executive occasionally exceed his budget for the sake of prompt action. This freedom will give him the incentive and opportunity to demonstrate his ability.

*Control of Expenses*

Budgets, as a part of a business concern's operating plan, are used frequently by management to control expenses. They serve as a reviewing device for the evaluation of operating results predicted on the master plan that was approved at the beginning of the business period. In this way, budgets become an important factor in motivating an organization. They serve as an incentive for personnel to accomplish the company objective. They provide a means by which all levels of management are held responsible for performance.

When budgets are compared with actual operation results, discrepancies are brought out. In this way, management becomes aware of organizational weaknesses and can continue its never-ending efforts to control expenses.

## Cost Accounting

The chart of accounts directs the financial transactions of a business into the proper channels. Although accounts must be designed to facilitate the preparation of conventional financial statements, they can also be subdivided in order that book records can be made as useful as possible to utility executives. In other words, accounting can effectively serve the needs of management beyond its usual purpose of recording business facts and determining profit and loss.

*Coding System*

A coding or numbering system used in accounting should be designed to facilitate comparisons with the budget. In this way, the realities of the financial situation, which may have already developed in variance to the original plan of management, will be apparent when the actual expenses are compared with the budget. The coding system should also provide for sufficient segregation of costs, so that management can be made aware of transactions without having to make extensive additional analyses.

The coding system provides for segregation of costs into natural divisions of work performed by particular groups. With supplies and expenses,

for example, there would be a separate account for each department. It should be obvious that if expenses authorized by different executives are charged to the same account, without any further subdivisions, the accounting records will be of little use to management in the control of expenses. The accounting department's classification of accounts should also provide for a list of possible items of income and expense for each phase of utility operations. Without such a list, it is inevitable that different people using the budget and accounting classifications will interpret the accounts differently, and possibly charge the same item to one account in the budget and to another in the books.

To make a budget system successful, expenses must be classified with as much care as is exercised in the safeguarding of cash. Responsibility for costs can only be established when it is clearly understood what items of income and expense are to be included in utility operations and when no changes are allowed without informing all those concerned before the change is made effective. When areas of responsibility for each executive form a definite part of the accounting setup, a means is provided for measuring accomplishments against the predetermined budgetary standards for all levels of the organization. One way to pinpoint responsibility for deviations from the operating budget is to design the accounting system so that cost data are passed upward through organizational lines and are accumulated and reported at various levels of responsibility.

**Budgetary Deviations**

A system of providing reports of cost data to various management levels is needed for an effective cost control program. The lower the level of management, the more detailed the reports should be. Reports should compare actual costs with budgetary estimates in a manner that will readily permit upper echelons of management to ascertain the performance of subordinates. Provision should also be made to consolidate into summary reports for top management the detailed information furnished lower levels. With the aid of reports comparing actual and budgetary figures for all management levels, responsibility for budgetary deviations can easily be pinpointed. Determining the underlying causes for the deviations is a more difficult task.

Budgeting and reporting systems defining areas of responsibility have been adopted by many utilities with the aim of helping management analyze and control costs. A basic function of these systems is to report cost data to the persons who are responsible for the costs and who can do something about keeping them within limits. Under such systems, accounting reports are simple, concise, and easy to understand because they reflect natural divisions of work. Also, areas of responsibility for costs are clearly indicated in these reports because they do not include accounting allocations required by regulatory commissions. Furthermore, cost distribution is improved, for it is obvious that greater accuracy in reporting results when an account for a department pertains only to the work of that department. A natural result of having concise and specific reports is that persons responsible for incurring certain costs will compare actual costs with budget estimates and, in effect, become auditors of the reports. They will be very

prompt in notifying the accountants about errors in classification.

It should be pointed out that accomplishments can be measured by other than budgetary standards. Management should know not only how costs compare with budget estimates, but also how the actual work performed compares with the planned-for objective.

It is entirely possible, in a typical operation such as meter reading, that budgetary estimates are met exactly. This may not be a true picture because the number of meters read may have decreased substantially from previous periods that show the same cost of labor. In other instances, work on one project may be stopped when the limits prescribed in the budget are reached and labor diverted to other purposes. This situation may appear satisfactory from a reporting basis, but it is sometimes preferable to complete the work rather than meet the budget.

Comparisons of unit costs with prior periods can indicate the cost trend. With respect to utilities, in which the same activities are carried out in different locations, it is possible to compare accomplishments and determine responsibility for inefficient operations.

*Analysis*

Effective reporting goes beyond the mere presentation of figures drawn from the accounts. It is necessary that an analysis be made to determine both the responsibility for budgetary deviations and the underlying causes or reasons for the departures. With the budgeting and reporting system described, the responsibility aspect is established without further analyses, but the cause of the deviation may or may not have been possible to control by the person responsible for making the expenditure.

Accounts must be analyzed in sufficient detail so that department heads can evaluate the figures reported and decide on corrective action Failure to determine causes of deviations quickly, may make remedial action impossible, for at a later date the cause of the deviation may be indeterminable.

An explanation of budgetary deviations in terms of underlying causes is necessary if management is to evaluate the performance of subordinates. Special conditions, such as excessive line leaks, may be responsible for a large increase in maintenance and labor costs for a pipeline department. On the other hand, postponable costs, or costs that can be shifted to future accounts with few or no indications of the efficiency of current operations, may remain hidden in the accounts for a long period of time if only budgetary deviations are checked. Deviations attributable to variations in quantity and price of materials should be analyzed for an evaluation of work performed. When management can readily check to see that the money it budgeted for a project has been spent for that project, when all hidden costs can be exposed, then an ideal system of cost control is at hand.

Any analysis of budgetary deviations should, of course, separate favorable and unfavorable deviations, in order to distinguish between satisfactory and unsatisfactory performance. A special effort should be made to see if any trend is being established. Finally, after the responsibility for a deviation has been assigned and the underlying cause determined, classified as controllable or uncontrollable, reports to management should be prepared and interpreted to indicate what success has been had in controlling the costs of current operations.

**Reports to Management**

Summary reports that consolidate the detailed information furnished lower echelons are regularly furnished to top management. In reviewing the data of current operations, management concentrates on deviations from predetermined objectives. When operations are progressing according to budgetary forecasts, little time is spent in studying the reports.

Executives should not be burdened with reports that include too many details. If they have to study and analyze the data, they are spending valuable time at a task that can be largely delegated. More and more reliance is being placed on the controller or on a budget officer to screen out the important items and to highlight the significance of the data.

Reports must not only tell a story but also serve a practical purpose. A report of a $1,000,000 inventory is meaningless unless it is related to other facts explained in plain terms. For example, the report may indicate that the inventory represents a 5-month supply or that it is excessive by a certain number of dollars. It should be so written that it forms a basis for action. A report on sums spent for engineering salaries, for example, even when the salaries are compared to budgetary estimates, is not as meaningful as a report on salary costs for individual projects and the overhead costs not allocated to specific jobs. Management can tell from this type of report what has caused engineering expenses to be high. It can then decide what, if any, action must be taken.

No reports, except very brief ones, should go to management without appropriate comments. This is a requirement. It is not sufficient to report a fact without giving an explanation of how it has come about. Provision should also be made for followups on remedial action as a part of the overall task of controlling costs and gaging performances. With the followup, an evaluation can be made of the remedial action, and further corrective measures can be taken if necessary. An analysis of costs or performance is wasted effort unless corrective action is taken and a followup made to evaluate the action.

***Charles E. Hemphill***———

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One of the most persistent and exasperating problems that business management must face is the control of expenditures. Except in relatively small businesses, cash or goods are expended for so many diverse needs, and in some cases over such a wide geographic area, that controls are vital and necessary if the business enterprise is to avoid loss. The business of water supply is no different from other businesses in this respect.

In some industries, projections of activity beyond the immediate future are based on rather broad estimates of market size. Water utilities, on the other hand, have their requirements spelled out much more clearly in the statistics charting the rapid growth of the nation's population. Meeting this phenomenal growth with adequate distribution systems and good service to the customer is going to be a test for all water utilities. A very important part of their success in passing this test will be an ability to plan for and control funds at their disposal.

Years ago, management may have attempted to keep a direct and per-

sonal control over expenditures, but it must have discovered soon that one man or relatively few men were not enough to handle the job. Because the top management of a utility cannot supervise every expenditure of cash or material, controls over costs must come from an organized effort. Experience has proved that the ability to organize a plan for controlling costs is as important as the ability to organize any other phase of a business.

## Responsibility Accounting

During the last few years, the problem of controlling expenditures has prompted top management in many organizations to consider delegating this responsibility throughout the organization. By making specific assignments and then checking on performance with the aid of periodic reports, top administrators can distribute work loads and improve results as well. This approach has been found to be logical and easily understood by operating personnel who actually play the key roles in such a program. The concept of delegating cost control responsibilities is the basis for what has been referred to during the past few years as responsibility accounting. This is a system for reporting the expenditures made by each department, section, or other responsibility area within an organization. The periodic reports prepared for each of these areas show only those costs for which the area is responsible. This system does not limit the reporting of expenditures to foremen of line departments or to other supervisors in the lower levels of an organization. Expenditures are summarized for all levels, to and including the chief administrative officer.

To be effective, such a system of responsibility reporting must be individualistic. Although there are certain basic principles to be followed, the reports, which are the heart of responsibility accounting, must be tailor-made for an organization. The costs reported should be those actually incurred in each organizational area under the control of a particular supervisor or manager.

### *Basic Philosophy*

Some administrators have stated that identifying and assigning specific responsibilities for expenditures are objectives in themselves. On the other hand, it is generally held that a reporting system of this kind is most effective when current expenditures are compared with plans made in advance. With financial forecasts and operating budgets, the reporting system makes it possible to detect where the mark is being missed, by how much, and who is having the problem. This financial planning is essential for establishing a basis for relating current performance to original objectives, not only for the information of top management, but also for the benefit of departmental supervisors.

The basic philosophy of responsibility accounting for controlling expenditures calls for a personalized accounting statement from each department head. The person responsible is shown how his original budget compares with his expenditures for a specific period. In developing his own departmental budget, the head of a department participates on the management team. Instead of receiving a budget prepared by someone else, for which he consequently feels little responsibility, the department head realizes that this is *his* budget, which will be used in preparing *his* reports as part of an overall plan. If he appre-

ciates the fact that the performance of his area of operation is vital to the fulfillment of utility goals, then he will have a sense of responsibility for his own performance and an appreciation of the need to keep within the plan that he has assisted in formulating. In creating this kind of company spirit, management has, in effect, said to its executives: The responsibility for preparing the total financial plan of utility operations for the coming year will be divided, and a portion of this responsibility will be assigned to you. It will be your responsibility to evaluate the reports that you regularly receive and to determine from them whether or not you are conforming to the plan. If you and all the others meet or better the plan, the organization will have a good year. If you do not meet the plan, find out why not, and then notify your supervisor in the same way that the president or chief administrative officer notifies the board of directors or an equivalent group to which he is responsible.

## Classification of Expenditures

One of the features of responsibility accounting is that the operating reports, which go to all levels in the organization, can summarize expenditures under classifications that are most meaningful to individual supervisors. With this important feature, costs can be reported in terms other than the conventional classifications of accounts. Generally, the classifications selected by operating personnel are based on actual work performed. This flexibility in reporting expenditures allows a supervisor and his personnel to receive reports prepared in language they can best understand. These classifications can be routinely translated later into conventional classifications, so that the formal records of the company and any reports required for regulating agencies can be prepared in the prescribed manner.

## Summary

The goal of responsibility accounting is to provide reports that are clear, concise, and easily understood by personnel who are not accountants. If this reporting system is correctly designed for an organization, it will be logical, and a very useful tool for operating personnel. By making a department responsible only for the costs it actually incurs, and by having departmental supervisors report to their superiors any significant deviations from the original financial plan, management will have delegated much of the work of controlling costs to the people who are in the best position to do so.

# Pension and Retirement Plans

## Committee Report

*A report of Committee 4240 M—Pension and Retirement Plans, submitted by John G. Copley (Chairman), Gen. Mgr., Elmira Water Board, Elmira, N.Y. Other members of the committee were Leo Louis Jr., Peter C. Karalekas, Melvin P. Hatcher, Arthur P. Kuranz, Daniel P. Morse, and Claud R. Erickson.*

THE previous report of the committee, published in the October 1950 JOURNAL (*1*), noted a substantial increase in legislation permitting and encouraging the establishment of retirement plans in water supply organizations. This report was made primarily to determine if the legislation has actually led to the establishment of retirement plans benefiting water supply personnel.

Questionnaires were mailed to 434 privately owned and publicly owned utilities serving 30,000 or more customers. Replies were received from 280, or 64.5 per cent of the utilities representing 45 states. Because the retirement and pension plan problems of the utilities seemed to differ with the type of ownership, the two types were separated for analysis. The 33 privately owned utilities reporting were 12 per cent of the total, as compared with 247, or 88 per cent, that were publicly owned.

### Privately Owned Utilities

Under federal social security law, all privately owned utilities are required to collect social security contributions from their employees and to make an equal contribution from company funds. As social security legislation was enacted in 1935, all regular employees of a privately owned utility with more than 10 years of service would have the 40 quarters of coverage required to insure them fully for life under social security. In addition to social security coverage, 29 companies (88 per cent) reported privately administered retirement plans, with eighteen, or 62 per cent, of these plans being entirely financed by the utility—that is, without employee contributions.

### Publicly Owned Utilities

Of the 247 publicly owned utilities reporting, 235, or 95 per cent, reported some kind of retirement plan. It was encouraging to note that 58, or 25 per cent, had established their retirement plans since the 1950 committee report; 86 had either added or established social security coverage since the 1950 legislation permitting public agency coverage by social security.

### Death Benefits

Of all the questionnaires received from publicly owned utilities, only 3 per cent indicated no employee contributions, and only 1.5 per cent indicated no utility contributions. The vast majority, 92 per cent, of all the retirement plans reported, made membership in the plan mandatory for all

employees. The plans varied widely with regard to provision for a death benefit and payments to surviving widows. Although the reports indicated that 57 per cent of the plans provided a death benefit, a number of notes on the questionnaires pointed to a separate life insurance program, not considered a part of the retirement plan. Most of the plans made payment to widows an optional procedure. By paying a larger contribution or agreeing to a smaller pension, an employee could protect a surviving widow. If these options are included, about 78 per cent of the plans reported provided protection to widows.

**Cost Provisions**

The cost provisions of retirement plans differed widely, ranging from no contribution by the employee, to one plan that called for 14 per cent of the employee's salary. A majority of the plans designed to meet actuarial requirements determine the employee contribution on a basis of percentage of pay, the percentage increasing with the age of the employee at the time he joins the plan.

The cost to the employer or utility varied inversely with the employee's contribution, ranging from no cost to the entire cost. In a majority of the plans of publicly owned utilities, the employer or utility costs exceeded employee contributions by about 1.5 per cent of payroll to cover past service benefits and administrative costs.

**Retirement Provisions**

The age of retirement also varied in the plans submitted, ranging upward from 65 to 72, and downward to 55 years of age. A number of municipal plans were based on years of service rather than on age; these permitted retirement payments after 20, 25, or 30 years of service. The majority of the plans set 65 as the retirement age, with retirement mandatory at 70 and earlier retirement permitted on an optional basis; the latter required either greater employee contributions or lesser retirement benefits.

The unknown quantity in this report is the 35 per cent of the utilities not reporting. Under normal sampling conditions, a return of 65 per cent can be used to indicate the total picture. With regard to this study, it seems that a large number of the nonreporting utilities failed to return their questionnaires because they did not have a retirement plan to report. Even so, the 25 per cent increase in established plans during a 9-year period is very encouraging.

**Suggested Improvements**

The greatest promise for further improvement seems to be the continued extension of social security for municipal employees. The 1950 legislation noted in the committee's previous report permitted coverage for employees of publicly owned utilities not covered by a state or municipal plan. Legislation approved in 1954 permits the states to pass enabling acts to add social security to existing state and municipal plans, and many states have done so. The benefits under social security noted in the 1950 report have been further liberalized. The minimum monthly benefit is $33; the maximum family benefit is $254; and the average benefit is $98. The level of employee earnings used as a basis for deductions has been raised from $4,200 to $4,800 a year, and the rate for both employee and employer is now 2.5 per cent. The advantage of social security coverage in addition to

or supplementing existing plans is the protection given the surviving widow with young children if the breadwinner of the family dies. Very few retirement plans make any provision for this type of insurance.

With the information available from the questionnaires, the committee considered suggestions for establishing an improved retirement plan, but opinions on the subject varied greatly. The first consideration was a plan that would continue indefinitely into the future. If a plan provides benefits that are too numerous or too large, after a few years of operation a utility will find its costs excessive. As a result, the plan will have to be modified and the employees' expectations curbed. Another fundamental consideration in designing a plan is to make it sufficiently attractive, so that employees will choose to stay on the job and not be tempted to leave the utility even when small salary increases are offered elsewhere.

The main difference of opinion among committee members dealt with the relative advantages of contributory and noncontributory plans. The committee, through the splendid efforts of Claud R. Erickson, designed a noncontributory plan that is on file in the New York office of AWWA. The advantages claimed for the noncontributory plan are: it keeps the utility in complete control of the plan; it requires less office accounting than a contributory plan; and it improves employee morale because there is no decrease in take-home pay. This type of plan is being used more and more in privately owned utilities and in many nonprofit organizations, such as hospitals and welfare societies.

The proponents of the contributory pension and retirement plan feel that it puts the basic responsibility of providing for an employee's future where it really belongs—on the employee. The role of the employer is that of an active supporter. Also, of course, the contributory plan can serve as an enforced savings plan for the employee. In either instance, it gives the employee an incentive to plan his own future. When the questionnaires were returned, approximately 150 existing plans for the contributory type of pension were received. These plans have also been placed on file in the New York office of AWWA. With both types of plans on file, there is now available for all utilities a program that can meet their desires and requirements.

The committee recommends that, in any event, professional advice be sought from a consulting actuary whenever a pension plan is to be established. There are many consultant firms with wide experience in pension and retirement plans that can save the utility a great deal of time, effort, and money. Legal advice is also essential, and any plan in its final form should be submitted to the US Bureau of Internal Revenue for approval, for the protection of the employee.

## Conclusion

The committee feels that substantial progress has been made in the last 9 years in increasing the security of the water utility employee by the establishment of pension plans and the addition of social security benefits for municipal employees. Continued progress will depend upon the efforts of individual utilities.

## Reference

1. COMMITTEE REPORT. State Pension and Retirement Legislation in 1949. *Jour. AWWA*, **42**:905 (Oct. 1950).

# Safety in the Water Supply Industry

*Charles H. Franklin Jr. and Garvin H. Dyer*

*A contribution to the Journal by Charles H. Franklin Jr., Safety Director, and Garvin H. Dyer, Vice-Pres., both of Independence Div., Missouri Water Co., Independence, Mo.*

DURING the second half of the nineteenth century, when industry began to expand and production rates and schedules climbed to unheard-of heights, it was necessary to install new machines and to increase the personnel to operate the larger factories. The machines were either poorly guarded or had no safeguards whatsoever, and machine placement and methods of operation were hazardous to the employee. The new personnel were largely unskilled and were certainly given no safety training. Under such conditions accidents of every type, and in large numbers, were bound to occur. It soon became evident that something had to be done to halt the tremendous accident toll.

In 1877 the state of Massachusetts passed a law requiring that all dangerous machinery be provided with guards. In 1906 the railroads and the steel industry began full safety programs. In 1911 the first Workman's Compensation Act was passed by the state of Wisconsin. The safety movement was underway. During World War I, more and more industries started safety programs to comply with the government's urgent request to conserve manpower. After the war, a safety program was an integral part of almost every industry in the nation.

## Safety in Water Utilities

In the water industry today, accidents have given new meaning to the formula for its basic product, $H_2O$: "Happens Too Often." Water utility men the nation over are tired of having accidents "happen too often" in their daily work. They are also considerably up in arms over the needless waste of manpower and money for preventable accidents. They are actively engaged in a safety movement that is gaining tremendous momentum. Before exploring the motives behind this movement, the methods being used, and the accomplishments, hopes and plans for the future, one ought to take a brief look at the water supply industry itself.

On a weight basis, the water supply industry leads all others in production. In 1958, the steel industry produced 85,000,000 tons of steel. The water industry produces the same tonnage of water in just one day. During 1958, 50,700,000 tons of oil were produced. Water utility men produce the same tonnage of water in only 16 hr. To match the yearly tonnage of bituminous coal, the water industry would operate but a short 7 days. Only 9 days of operation would be required to equal the combined yearly output of all three of the industries mentioned.

Not only is water production large in terms of tons, but its transportation is also on a large scale. The water industry transports to over 125,000,000 people in the United States almost 80,000,000 tons of safe drinking water each and every day. In a little less

than one month, the water industry transports more tonnage than all of the nation's railroads hauled during 1958. The water supply industry is a giant in production and in transportation—but it is only a novice in the field of safety.

Many water utilities had outdated systems not too many years ago. The increase in population and the trend toward suburban living put considerable pressure on these utilities to expand and meet the requests for new facilities in outlying areas. Expansion in the water industry followed somewhat the same pattern as other industrial expansion. New equipment had to be secured to meet the demands. New personnel had to be hired to operate the equipment. While expansion to outlying areas was underway, a need to improve the old, antiquated systems also arose. In the march to modernize and expand, a large portion of the work was still done with manpower alone. The bulk of the new employees were unskilled and had no safety training in water utility construction. These conditions combined to cause an astonishing rise in the number and severity of accidents. Back injuries were frequent, and eye injuries and burns from lead or other jointing materials also increased. The fracture cases increased as a result of unsafe handling of materials, cave-ins, and other mishaps. Unsafe working methods hindered production, damaged public relations in the community, and increased insurance rates to utilities.

When the industry finally confronted the problem of reducing this waste of manpower and money, it was hampered by many factors. There were many plants involved, most of them small. The units of operation were largely isolated and most water utility employees, because of low pay scales, were not the best of skilled laborers. These and other factors combined to give the industry a high accident frequency rating—a rating that showed little prospect of coming down.

## AWWA Manual

One of the biggest aids in the battle against accidents appeared in 1950. During that year AWWA established a committee to investigate the accident problem and to make recommendations. The result of the splendid work of this committee was the AWWA manual, *Safety Practice for Water Utilities* (*1*). In terms of water utility literature, it is a best seller.

The manual is divided into three parts. Part 1 deals with the urgent need for a safety program in every utility. It explains the method of calculation of injury rates, the cost of injuries, and the many benefits of safety programs. Part 2 presents clear and concise recommendations for starting and maintaining a program. The manual has been a great aid to many operators who were always a bit uncertain of how to get a safety program off on the right foot. Part 3 deals solely with safe working practices and covers in detail almost every kind of job in the water utility field. The safety manual has helped to start many safety programs where they did not exist before. As one company put it, "Our copies of the manual are dogeared, dirty, and torn from use, and we have a nice clean stack of accident report forms going to waste."

## Safety Programs

The safety programs being developed in the water supply industry are, for the most part, based on the material presented in the AWWA safety man-

ual. These programs are giving safety training to the unskilled employee. They are teaching the men safe work practices, how to be alert to the hazards of the industry, how to protect themselves and their fellow workers.

Along with these programs there is considerable distribution of personal protection, such as safety shoes. Hard hats are probably the last thing one would expect to find in the water industry; but, with the use of heavy construction equipment, such as overhead cranes, high loaders, backhoes, and equipment for trenching, the need for head protection became quite evident. At the Missouri Water Co., Independence, Mo., a series of head injuries a few years ago demonstrated the need for head protection. Bump helmets for meter readers, who often must go into dark basements, are required gear. Eye protection is often a must.

In addition to teaching the application of safe practices to the water industry, the urgent need of off-the-job safety is also stressed. Much material is presented and distributed to the employee on this subject.

### Safety Progress

Many water utilities have had gratifying results from safety programs. Perhaps the most progress has been made at the Akron (Ohio) Bureau of Water Supply. In 1953 the National Safety Council awarded this utility the Award of Honor for the outstanding performance of 447,095 man-hr of water works operation with only one lost-time injury. This represented an injury frequency rate of 2.2, as compared to the industry's rating of 23.9 for that year. This also was the first time this highest of all safety awards was won by a water utility.

Although all water utilities have not earned awards, a great many have substantially lowered their injury frequency rates after starting safety programs. Richmond, Va., reduced its rate from 26.1 in 1953 to 16.8 in 1954. The Kansas City, Mo., water utility has made great progress with its safety program. In 1951 its frequency rate was 82.45, but in 1957 it was only 11.26. In the past year, it is estimated that Miami, Fla., saved more than $25,000 in insurance rates and man-hours as a direct result of the 3-year-old safety program.

The Missouri Water Co., in Independence, has been able to lower its frequency rating from 51.34 in 1955 to 7.20 in 1957. Numerous methods have been used in presenting the safety program to its employees. The utility has tried to create a program that the men could call their own; it should be their program inasmuch as they are the ones who gain the most. Group meetings are held once a month on company time, and the programs cover a wide variety of safety subjects. Frequently several of the men take part in sketches that illustrate safe work practices. Whenever a program includes some of the men, it is a sure success and beneficial to everyone. Motion pictures, sketch talks, and lectures are also used. Recently the construction crew started weekly tailboard talks, at which each week a different employee talks on any safety subject he chooses. The talks have been quite effective, as the record shows. The crew has worked for 27 months with only one lost-time injury.

At Independence, contests are used to stimulate interest. Generally these are for a 6-month period, and the men are divided into four teams. Each team is penalized for each accident, and the team with the best score is

the winner. In the first contest, each man on the winning team received a wallet as an award. In other contests such things as lighters and pocket knives have been awarded. The National Safety Council also sponsors a contest between utilities over the nation. So far, the Missouri Water Co. not been higher than sixth place. It is, however, still trying for the top position.

## Conclusion

Safety in the water supply industry is moving forward each year. To illustrate this progress, one need only to call attention to the overall reduction in injury frequency ratings. In 1947 the industry's average rating was 31.83, so there has been a reduction of almost 50 per cent in 10 years. The industry's severity rating has been reduced from 1,980 in 1947 to 995 in 1957. More small plants are joining the safety movement and benefiting from it in many ways.

Water utilities are participating in various community safety movements, and some utilities sponsor other safety campaigns in the community, such as bicycle safety, school crossing safety, and traffic safety.

Through safety programs, newer and safer equipment is being developed and used. The recent development of a new method of joining cast-iron pipe has eliminated the hazards of using lead or special jointing compounds. Reduction of such hazards has greatly decreased the accident frequency. Through the training portions of safety programs, water utility personnel are becoming more alert to job hazards and more aware of the importance of working safely. With safety-conscious personnel, better and safer equipment, and safer methods of working, the water industry is better able to keep pace with the demand for its services.

Safety programs must continue in the future, always improving in effectiveness and scope. Greater efforts must be made to promote safety campaigns. It has been proved time and time again that the safety-conscious employee is safer at work than he is at home. A safety-minded individual promotes safety in everything he does, whether at his job, in his home life, or in his community life.

It is vital to the water industry that all plants, large and small alike, incorporate in their daily work schedules a time for safety programs, in order to teach their employees to work and live safely. The water supply industry can make a greater contribution to society than the production of water alone. To produce a better product, to offer better service, to foster better employee and public relations, and to do all of these things safely—these are real challenges to the water supply industry.

## Reference

1. *Safety Practice for Water Utilities.* AWWA Manual M3, Am. Wtr. Wks. Assn., New York (1958). Price, for general sales, $1.50; to members paying in advance, $1.20; to members ordering quantities of 20 or more, $1.00 per copy.

# Effect of Disinfecting Agents on Evaporation Reduction With Hexadecanol

***Shih Lu Chang, Graham Walton, Richard L. Woodward, and Bernard B. Berger***

*A contribution to the Journal by Shih Lu Chang, Medical Dir., Graham Walton, San. Eng. Dir., Richard L. Woodward, Chief Water Supply, and Bernard B. Berger, Chief, Water Supply & Pollution Research, all of the Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.*

As early as 1925, laboratory research (*1*) had shown that monomolecular films could be used to suppress evaporation from a water surface, and Langmuir and Schaefer (*2*) had reported in 1943 that hexadecanol was one of the chemicals best suited for this purpose. The first application of hexadecanol to reduce consumptive evaporation loss in a storage reservoir was made in 1953 by Mansfield (*3*) in Australia. From his early field studies, Mansfield (*4*) reported 20–30 per cent reduction in evaporation losses, and more recently he has reported a 37 per cent reduction over a 14-day test period for a large reservoir (*5*).

In 1954, Wark presented a paper on the Australian studies before the San Antonio section of the American Chemical Society. It aroused great interest. Since then numerous investigators have studied various phases of the problem. The Southwest Research Institute (*6*), after making laboratory studies of more than 150 different chemicals or similar products of different manufacturers, concluded that the long-chain alcohols—dodecanol through octadecanol—were best suited for evaporation control. The USPHS investigated the potential health hazard to humans and gave approval to the use of hexadecanol (*7*) and octadecanol (*8*) when applied in the manner and amounts proposed for evaporation control.

Early studies in the United States indicated the need for constant renewal of the monolayer. Various investigators noted an accumulation of biological growths on hexadecanol pellets and floats that appeared to interfere with the dispersion needed to maintain the film. The Southwest Research Institute observed accumulations of algae and tried to inhibit such growths by using copper screen cages for holding the pellets and hexadecanol formulations containing copper sulfate, but the results were not satisfactory.

Meanwhile, studies were being made by the US Bureau of Reclamation (*9*), Robert A. Taft Sanitary Engineering Center, and Silvey (*10*) on the effect of hexadecanol on fish and other aquatic life. Henderson and Pickering (*11*), during their studies on fish, noted the depletion of oxygen in a water-hexadecanol emulsion and suggested that hexadecanol was attacked by bacteria or other organisms. Thereafter, Ludzack and Ettinger (*12*) demonstrated the biochemical destruction of hexadecanol and commented that it might be a significant economic factor.

During the Kid's Lake studies (*10*), Silvey noted that the presence of hexadecanol caused increased growth of *Pseudomonas*.

With this background a study was undertaken to determine the feasibility of incorporating a bactericide in a hexadecanol formulation to inhibit biologic growths and prolong the effective film life obtainable from a single application.

The study included investigations of physical characteristics of hexadecanol films and their formations (Table 1), laboratory bench experiments on savings in evaporation, outdoor stock tank evaporation experiments with selected hexadecanol formulations, hexadecanol-attacking bacteria, and the inhibiting effects of the various hexadecanol formulations on bacterial growth.

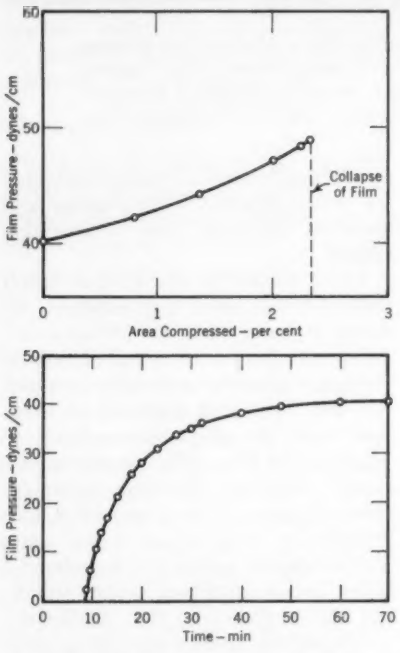


**Fig. 1. Surface Pressure—Time Relationship and Compressibility of Hexadecanol Film**

*The perimeter of the pellet was 78 mm; the area of the water surface was 700 sq cm; and the temperature was 24.8°C.*

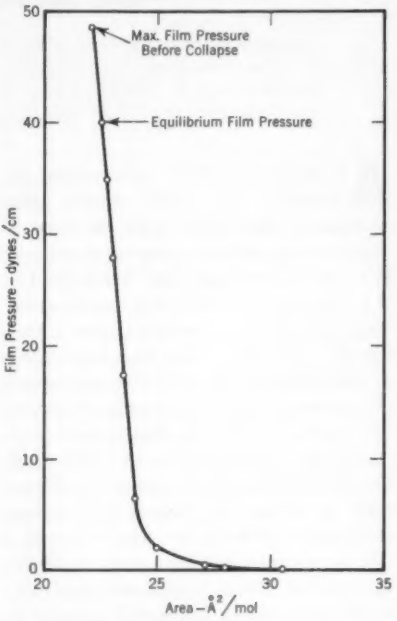


**Fig. 2. Effect of Molecular Area on Surface Pressure of Hexadecanol Film**

*The temperature was 24.8°C.*

## Physical Characteristics

The formation of a film from a 25-mm diameter pellet (78-mm water contact perimeter) of 99 per cent pure hexadecanol was studied at 25°C by measurement of the film pressure with a hydrophil balance. Three separate determinations gave nearly identical results. The data from one of them are plotted in Fig. 1. A measurable

film pressure was first detected in 9 min. Thereafter it increased rapidly during the next 20 min. and reached a state of equilibrium at 40.4 dynes/cm after approximately 50 min.

Studies were made also of the compressibility of such films (Fig. 1), which collapsed when compressed to 97.7 per cent of their original areas. The film pressure at rupture was 48.6 dynes/cm.

The areas occupied by a molecule of hexadecanol at various film pressures were studied. The weight of hexadecanol in the film was determined by the loss in weight of the 99 per cent pure pellet used to form the film in the pan of the hydrophil balance. As the film was compressed, both surface area and film pressure readings were taken. The area, measured in square angstrom units, occupied by each molecule under different film pressures was computed by the formula:

$$A_m = \frac{(A_f \times 10^{16}) \times 242.44}{W \times 6.02 \times 10^{23}}$$

in which $A_m$ is the molecular area, in square angstrom units; $A_f$ is the film area, in millimeters; $W$ is the weight of hecadecanol in the film, in grams; 242.44 is the molecular weight of hexadecanol; and $6.02 \times 10^{23}$ is Avogadro's number.

The data obtained from three separate determinations were similar and those for one are plotted in Fig. 2. Very little film pressure is developed until the area occupied by each molecule falls below 25 sq Å, but further reduction of this area results in a rapid increase in the film pressure.

A study was made of the effect of the number of sources and their total water contact perimeter on the rate of film formation. Some of the results are shown in Fig. 3. As these results indicate that the number of sources is an important factor, the rate of film formation was investigated with a crystalline powder averaging approximately 0.1 mm in diameter. The results were poorer than expected. Further investigation revealed that particles of this size float on top of the water surface and thus provide relatively small water-contact perimeter. Additional observations of crystals of different sizes showed that the minimum diameter of a hexadecanol particle providing a maximum water contact perimeter is approximately 1.5 mm.

TABLE 1

*Hexadecanol Formulations Studied in Laboratory and Outdoor Studies*

| Additive | Amount Used *per cent* |
|---|---|
| None | 0 |
| None*† | 0 |
| Tribromomelamine (TBM) | 15 |
| Trichloromelamine (TCM) | 15 |
| Hexachloromelamine (HCM) | 15 |
| Pentachlorophenol (PCP) | 15 |
| Benzylchlorophenol (BCP) | 15 |
| Dichlorochloroanilinotriazine (DCT) | 15 |
| Trichlorocarbonilide (TCC)† | 15 |
| Bithionol | 1.5 |
| Iodine ($I_2$) | 2.5, 7.5 |

* Water chlorinated with chloramine-T to give a 1-hr chlorine residual of 4.5–5.5 ppm before addition of hexadecanol.
† Laboratory study only.

## Film Pressures

Equilibrium film pressures of hexadecanol and hexadecanol formulations, as determined by means of the hydrophil balance, are given in Table 2. All additives reduced the film pressure. Although it was recognized that such a decrease would result in a less efficient film for suppression of evaporation, the study was continued with the thought that the control of biological growths could prolong the useful life

of the hexadecanol film and thus more than offset the reduction in film pressure.

### Suppression of Evaporation

Based on the results of preliminary studies, hexadecanol formulations containing various additives were studied. These are given in Table 1.

In each study the hexadecanol, or hexadecanol formulation, was applied in the form of a coarse powder of a particle size averaging about 1 mm in diameter.

Small pails, 11 in. in diameter, and pans, 10 in. long by 7 in. wide, were filled to ½ in. from the top with distilled water inoculated with 2 ml/l of settled sewage. The hexadecanol formulations were applied at the rate of 4 mg/sq ft (0.4 lb/acre). Two controls were used, one with hexadecanol without additive, and the other a blank. Duplicate pans or pails were used for each formulation and control. Evaporation losses were determined by measuring the volume of water required to bring the water level, as determined with a point gage, to its original elevation. The measured evaporation was corrected by a factor previously determined for the location of each pan on the bench. All pans and pails were emptied and carefully cleaned before each run.

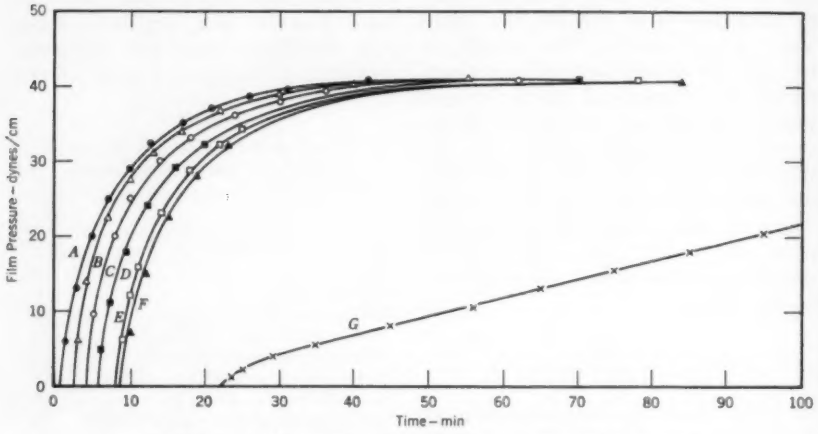


**Fig. 3. Effect of Perimeter and Number of Spreading Sources on Formation of Hexadecanol Film**

*The area of the water surface was 700 sq cm; temperature was 24.8°C. Curve* A—*40 crystals, estimated perimeter of 232 mm; Curve* B—*six pellets, total perimeter 79 mm; Curve* C—*disc, perimeter 92 mm; Curve* D—*three pellets, total perimeter 39.6 mm; Curve* E—*disc, perimeter 92 mm; Curve* F—*disc, perimeter 78 mm; Curve* G—*disc, perimeter 17 mm.*

Bench studies were made at three different locations. Location 1 was chosen so that air from the air-conditioning outlet wrinkled but did not break the water surface. At Location 2 a gentle breeze was produced over the surface, and at Location 3 the air movement was relatively unnoticeable.

Test results, expressed in percentage reduction of evaporation from untreated water surface, are summarized in Table 3. It is emphasized that these percentage reductions are average daily reductions for the total test period.

Limited outdoor studies were made using six stock tanks, 4 ft in diameter and 20 in. deep, and the more promising hexadecanol formulations. In each test, hexadecanol formulations were applied to two tanks; hexadecanol alone to two tanks; and two tanks were used to determine uncontrolled evaporation. Preliminary studies showed that corrections of evaporation data for tank positions were unnecessary. Other test procedures were similar to those used in the bench studies. Results are shown in Table 4.

## Bacteriologic Study

Microphotographs of the flora and fauna, obtained during the laboratory studies by touching the water surface with a cover slip, are shown in Fig. 4.

Materials removed from tanks, pans, and pails, to which hexadecanol formulations had been applied, were smeared on hexadecanol agar plates and incubated at 35°C. The bacteria isolated were highly motile, gram-negative, nonsporulating rods. Biochemical and infrared spectrophotometric characteristics of four of those isolated indicated that two of them were of the genus *Pseudomonas*, and two were of genus *Flavobacterium*.

Five pails were filled with distilled water to which had been added 3 ppm $NH_3NO_3$ and 1 ppm $Na_2HPO_4$. A suspension of washed cells of one *Pseudomonas* species and one *Flavobacterium* species was added to each of four pails. Two of these were treated with 5 mg/sq ft of hexadecanol powder. Samples were taken from each pail and examined bacteriologically. As the population density was essentially the same for each of three sampled depths, the average densities determined for each pail on three separate dates were used in plotting Fig. 5.

TABLE 2

*Film Pressures of Hexadecanol* and of Hexadecanol Formulations on Distilled Water at 25°C*

| Additive | | Film Pressure at Equilibrium *dynes/cm* | Standard Deviation *dynes/cm* |
|---|---|---|---|
| Type | Amt *per cent* | | |
| None | 0 | 40.4 | ±0.3 |
| | 0 | 40.4 | ±0.4 |
| TCM | 5 | 38.1 | ±0.2 |
| | 15 | 37.2 | ±0.4 |
| HCM | 5 | 38.2 | ±0.3 |
| | 15 | 36.8 | ±0.4 |
| TBM | 5 | 38.5 | ±0.2 |
| | 15 | 37.6 | ±0.3 |
| $I_2$ | 2.5 | 36.8 | ±0.2 |
| | 5 | 36.1 | ±0.2 |
| | 7.5 | 35.0 | ±0.3 |
| | 10 | 34.2 | ±0.4 |
| TCC | 5 | 38.7 | ±0.5 |
| | 15 | 38.0 | ±0.4 |
| Bithionol | 5 | 38.9 | ±0.3 |
| | 15 | 38.1 | ±0.2 |
| PCP | 5 | 39.0 | ±0.4 |
| | 15 | 38.2 | ±0.2 |
| BCP | 5 | 38.9 | ±0.3 |
| | 15 | 38.2 | +0.3 |
| DCT | 5 | 38.8 | ±0.2 |
| | 15 | 38.1 | ±0.3 |
| Tyrothricin | 5 | 35.0 | ±0.5 |

* 99 per cent pure in first test with no additive. 95 per cent pure in second test with no additive and in all trials thereafter.

TABLE 3

*Effects of Additives on Evaporation Control by Hexadecanol, Indoor Study, 24–25°C*

| Test Duration *days* | Avg Loss in Control *ml/day* | Reduction in Loss Over Control—*per cent* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No Additive | Chlorinated Water | 15% TBM | 15% TCM | 15% HCM | 15% PCP | 15% BCP | 15% TCC | 15% Bithionol | 15% DCT | HD* and $I_2$ |
| **Location 1** | | | | | | | | | | | | |
| 2 | 345 | 19 | 33 | 17 | 15 | 12 | | 16 | | 17 | | |
| | 425 | 23 | 37 | 20 | 17 | 15 | | 19 | | 19 | | |
| 3 | 365 | 10 | 34 | 18 | 5 | 12 | 19 | 18 | 6 | 11 | 7 | 6† |
| | 380 | 16 | 38 | 26 | 10 | 20 | 22 | 20 | 11 | 16 | 12 | 7‡ |
| | 410 | 18 | 38 | 26 | 17 | 23 | 22 | 21 | | 19 | 21 | |
| 4 | 310 | 6 | 34 | 10 | 14 | 13 | 12 | 17 | 5 | 5 | 7 | 8† |
| | 335 | 6 | 34 | 16 | 14 | 14 | 12 | 17 | 5 | 13 | 13 | 8‡ |
| | 410 | 12 | | 16 | 15 | 14 | 15 | 17 | 11 | 13 | 13 | |
| | 420 | 13 | | 18 | 16 | 17 | | | | 15 | 15 | |
| 5 | 350 | 7 | 34 | 12 | 8 | 12 | 10 | 10 | 2 | 8 | 7 | 7† |
| | 370 | 9 | 35 | 18 | 10 | 14 | 18 | 12 | 7 | 10 | 7 | 8‡ |
| **Location 2** | | | | | | | | | | | | |
| 2 | 260 | 15 | | 14 | 11 | | 15 | 12 | | 11 | 7 | |
| | 280 | 17 | | | | | | | | | | |
| 3 | 200 | 8 | | 16 | 9 | 13 | | 13 | 6 | 5 | | |
| | 265 | 11 | | | | | | | | | | |
| 4 | 265 | 11 | | | | | 9 | | | 0 | 5 | |
| 5 | 210 | 8 | | 13 | | 13 | | 9 | | 11 | | 11‡ |
| | 270 | 10 | | 19 | | | | | | | | |
| **Location 3** | | | | | | | | | | | | |
| 2 | 175 | 13 | | 8 | 7 | 10 | 10 | 10 | | 6 | 6 | 0† |
| | 175 | 17 | | 13 | 9 | | 14 | 12 | | 6 | 11 | 2‡ |
| 3 | 210 | 10 | | 15 | 13 | 4 | 15 | 13 | | 5 | 5 | |
| 4 | 120 | 9 | 22 | 8 | 3 | | 11 | 12 | 0 | 3 | 4 | 4‡ |
| 5 | 100 | 5 | 35 | 11 | 7 | 12 | 12 | 7 | 0 | 2 | 0 | 2† |
| | 125 | 7 | 38 | 13 | 12 | 12 | 12 | 10 | 0 | 9 | 3 | 2† |
| | 200 | 10 | | 16 | 14 | 13 | 12 | 11 | 5 | 12 | 5 | 10‡ |

* Hexadecanol.
† Formulation contained 7.5 per cent $I_2$.
‡ Formulation contained 2.5 per cent $I_2$.

TABLE 4

*Effect of Additives on Evaporation Control by Hexadecanol Film in Outdoor Study*

| Additive* | Test Duration *days* | Prevailing Water Temp. *°C* | Avg Loss in Control *ml/day* | Saving in Loss Over Control *per cent* | |
|---|---|---|---|---|---|
| | | | | HD Alone | HD and Additive |
| Bithionol | 2 | 28–31 | 520 | 18 | 7 |
| TCM | 2 | 26–30 | 320 | 14 | 12 |
| BCP | 3 | 26–30 | † | 11 | 14 |
| $I_2$‡ | 3 | 26–28 | 120§ | 10 | 19 |
| TBM | 4 | 26–30 | 380 | 8 | 5 |
| PCP | 4 | 26–29 | † | 11 | 16 |
| $I_2$‖ | 4 | 26–30 | 280 | 9 | 12 |
| DCT | 4 | 26–30 | † | 4 | 2 |
| HCM | 5 | 26–30 | 100§ | 10 | 9 |

* 15 per cent unless otherwise specified.
† Water was taken out in order to bring the control to its original level.
‡ 2.5 per cent.
§ Very high humidity was encountered.
‖ 7.5 per cent.

Studies were also made of the changes in film pressure during storage and the required compression to develop a film pressure of 40.4 dynes/cm in a water contaminated with sewage and one inoculated with *Pseudomonas* and *Flavobacterium*. The results are shown in Table 5.

## Discussion of Results

At equilibrium pressure the molecules in a hexadecanol film are so closely packed that they are squeezed out of the monolayer if the film is compressed by as little as 2.3 per cent of its original area. This, together with the hyperbolic shape of the curve showing film pressure as a function of time, is confirming evidence that hexadecanol forms a truly solid film by two-dimensional expansion.

A similar conclusion was reached by Harkins in analyzing the data obtained by Harkins, Copeland, and Adinoff in research on the behavior of stearic acid on water of pH 7.6 with $10^4$ molar $Ca^{++}$ ions (*13*).

The curve showing the area occupied by a molecule of hexadecanol in the film as a function of film pressure varies somewhat from a similar curve developed from Mansfield's data (*14*), but is in close agreement with one determined by Harkins (*13*). The area of 22.3 sq Å occupied by the molecule at rupture of the film, together with the average area of 16 sq Å, determined from x-ray photographs of crystals by Gladstone (*15*) indicates that the larger area occupied by the molecule in the film is not caused by Brownian movement, but rather to the larger base formed by the polar group in hydrogen bonding with water molecules. In addition, the difference in

TABLE 5

*Maintenance of Hexadecanol Film Pressure on Water Containing Bacteria Grown on Hexadecanol Agar and on Sewage-Contaminated Water*

| Time After Application Hexadecanol* *hr* | Film Pressure— *dynes/cm* | | Area Compressed in Order to Bring Film Pressure to 40.4 *dynes/cm* | |
|---|---|---|---|---|
| | Water Containing Bacteria† | Sewage-Contaminated Water | Water Containing Bacteria† | Sewage-Contaminated Water |
| 2 | 40.4 | 40.4 | none | none |
| 6 | 40.4 | 40.4 | none | none |
| 22 | 40.4 | 40.4 | none | none |
| 30 | 40.4 | 40.4 | none | none |
| 46‡ | 36.9 | 40.0 | 0.87 | 0.25 |
| 50‡ | 30.5 | 40.0 | 1.45 | 0.25 |
| 54‡ | 18.0 | 39.2 | 2.52 | 0.33 |
| 70§ | Zero | 15.0 | 31.10 | 2.40 |
| 78 | Zero | Zero | 31.00 | 32.00 |

* 0.4 lb/acre.
† *Pseudomonas* and *Flavobacterium*.
‡ Dust patches noticed on the water surfaces may have influenced the film pressure and compressibility.
§ Dust patches more apparent.

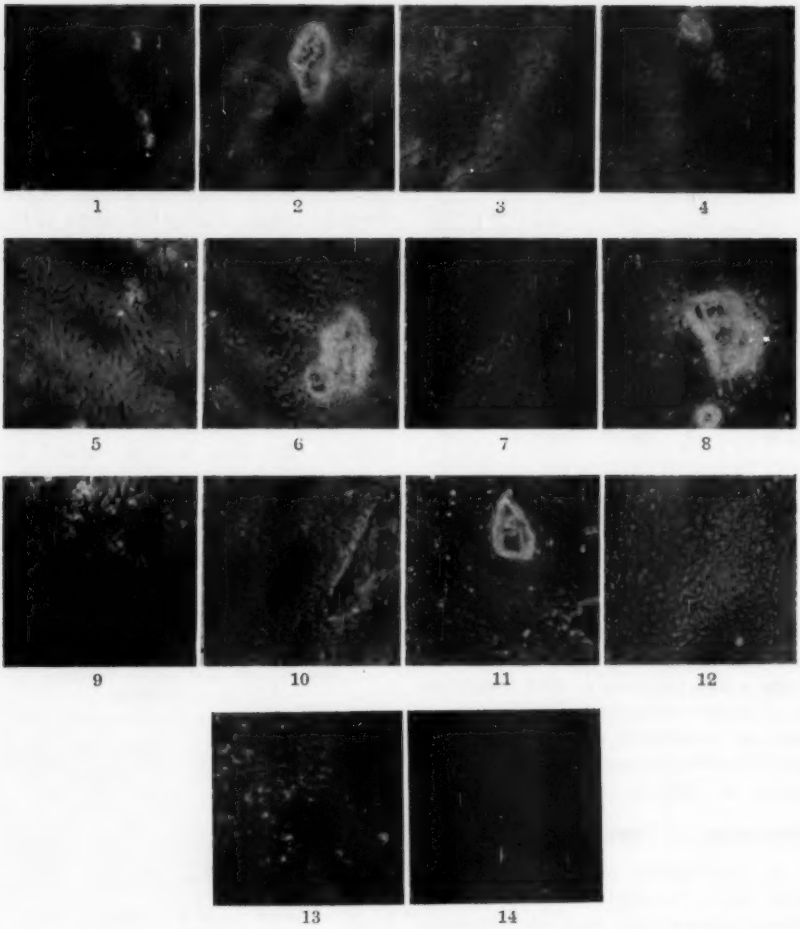


**Fig. 4. Bacteria in Water Surface With and Without Hexadecanol Film**

*(Explanation on facing page)*

the area occupied by the molecule in the film under equilibrium and that occupied under rupture pressure is evidence that the carbon chain of the molecule does not have to stand vertically, as has been imagined, but may be tilted slightly.

Of more practical importance are the data concerning the number and size of the hexadecanol sources on the water surface. The results are not quantitative, but they do indicate that a large number of sources is desirable. If this is true, floats, or floating cages containing pellets, are ineffective means for dispensing hexadecanol. A better method is the broadcasting, in air or in water spray, of powder or

pellets of the smallest dimension that will float and still provide a maximum water contact perimeter. Observations with a microscope indicate that the minimum diameter for such a particle is approximately 1.5 mm.

The equilibrium film pressures of hexadecanol formulations containing various percentages of different bactericides provided valuable guidance in selecting the formulation for further study. The data shown in Table 2 resulted in the discarding of Tyrothricin and the higher concentration of iodine and the decision to use 15 per cent bactericidal formulations for further study.

The total percentage reduction in evaporation loss for each individual bench experiment has been shown in Table 3. On comparison of the overall results, a trend of decreasing percentage reduction is noted as the data for Locations 1, 2, and 3 are examined in order. This trend shows that the percentage of evaporation reduction increases with the evaporation rate.

### Bacteriologic Factors

In planning the study it was decided to determine the potential water savings under conditions of more limited biologic activity. Hexadecanol was applied to water prechlorinated to maintain a minimum chlorine residual of 1 ppm at the end of the test periods. The average data for hexadecanol on chlorinated water for Location 1 were used to plot Fig. 6. The result, which is a straight line, and the microscopic findings are evidence that there was no bacterial interference with mainte-

**Explanation for Fig. 4**

*The differences in bacterial growth noted below include variations due to differences in distribution of bacteria. Microphotographs 5, 9, and 11 are 240×; all others are 120 ×.*

*1—From surface of water of an untreated control tank in Location 1 after 24 hr; dust particles are visible.*

*2—From water surface 24 hr after application of hexadecanol in Location 2; hexadecanol crystals are free from bacterial growth.*

*3—Same as No. 1 after 48 hr; bacterial clumps are visible.*

*4—Same as No. 2 after 48 hr; bacterial growth has developed on crystal.*

*5—Same as No. 4 at twice the magnification; the bacillary shape of the bacteria is visible.*

*6—From water surface 72 hr after application of hexadecanol with 15 per cent TBM in Location 1; there are relatively fewer bacteria than in No. 4.*

*7—Same as No. 1 after 72 hr; there is an increase in bacterial population.*

*8—Same as No. 4 after 72 hr; there is increased bacterial growth around the crystal.*

*9—Same as No. 8 at twice the magnification; there is a greater variation in size of the bacilli than in No. 5.*

*10—Same as No. 1 after 96 hr; the bacterial population is rich.*

*11—Same as No. 2 after 96 hr; there is dense growth around the crystal.*

*12—Same as No. 11 magnified twice as much; bacteria seem to be of the same morphological group.*

*13—Same as No. 6 after 96 hr; there is slightly less bacterial growth than in No. 11.*

*14—From water surface 96 hr after application of hexadecanol and 15 per cent HCM in Location 1; there are distinctly fewer bacteria than in No. 11.*

nance of the hexadecanol monolayer over the 5-day test period.

Table 3 shows that hexadecanol alone provided the most effective evaporation control over a 2-day period. This is to be expected, as each added bactericide resulted in a hexadecanol formulation having a reduced equilibrium film pressure. If the pails and pans had not been carefully

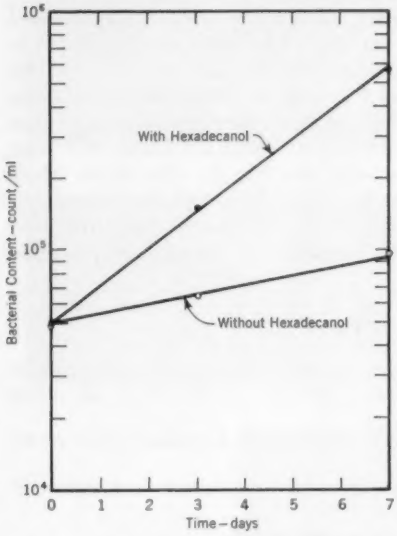


**Fig. 5. Influence of Hexadecanol Film of Growth of *Flavobacterium* and *Pseudomonas***

*The water contained 3 ppm $NH_4NO_3$ and 1 ppm $Na_2HPO_4$; temperature was 24.8°C.*

cleaned prior to each experiment, the water would have been seeded with heavy growths of hexadecanol-attacking bacteria, and the period of control probably would have been substantially shorter than 2 days.

## Effectiveness of Formulations

According to the results of the 5-day experiments at Location 1, the hexadecanol formulations containing TBM, HCM, PCP, and BCP, were most effective in prolonging the life of the monomolecular film. The indicated water saving for the hexadecanol formulation containing HCM is compared with those for hexadecanol alone in Fig. 6.

The percentage reduction in evaporation loss for the outdoor tests shows that the TBM and HCM formulations, which had shown good results in the bench studies, were ineffective. This discrepancy is believed due to decomposition of these two compounds on exposure to sunlight. The reverse was true with the $I_2$ formulations, which apparently released $I_2$ from the $(C_{16}H_{33}OH)_6 \cdot I_2$ complex. The release of $I_2$ provided disinfection and permitted the hexadecanol to form a monomolecular layer of increased film pressure.

PCP and BCP formulations showed substantial evaporation reduction for both bench and outdoor experiments. These reductions may be attributed to the relatively high film pressures, fair bacteriostatic properties, and high stabilities of the formulations.

The microphotographs in Fig. 4 show that a substantial accumulation of bacteria develops on clean water surfaces and that, in the presence of hexadecanol, their growth is accelerated. In the bench studies, the presence of TBM, HCM, PCP, or BCP appears to have retarded such growths. Microscopic examinations of samples from the outdoor studies showed that the PCP and BCP formulations were effective in reducing growths, but that those containing TBM and HCM were not.

Two distinct species of two genera of bacteria, *Pseudomonas* and *Flavobacterium*, were identified during the test. Data have been presented show-

ing that the presence of hexadecanol promotes rapid growths of these genera of bacteria and that when hexadecanol is applied to water heavily seeded with them, the monomolecular film breaks down more rapidly than when the water is seeded with sewage bacteria.

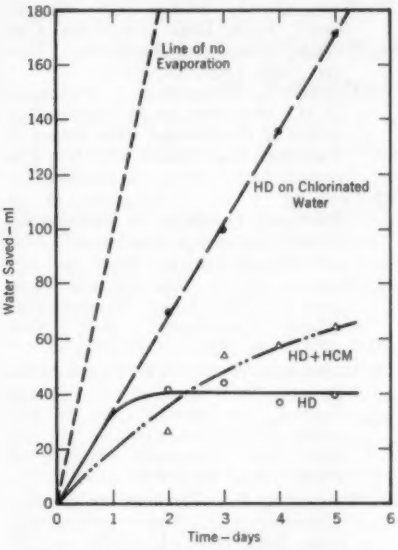


**Fig. 6. Water Saving Through Single Treatment With Various Hexadecanol Formulations**

*The curves were plotted from average data given in Table 2. The amounts saved were based on an assumed evaporation rate of 100 ml per day.*

## Conclusions

Convincing evidence has been obtained that the presence of hexadecanol promotes the growth of certain bacteria, among which are species of the genera *Pseudomonas* and *Flavobacterium*, and that the growth of these organisms is accompanied by destruction of the film and interference with its repair.

Laboratory studies indicate that, for maximum effectiveness, hexadecanol should be applied in the form of particles 1.5–2.0 mm in diameter and dispersed over the water surface.

A substantial increase in water savings is obtainable with hexadecanol if the biologic growths interfering with film formation and repair can be inhibited.

Although hexadecanol alone was most effective in reducing evaporation losses over a two-day period, the formulations containing certain bactericides proved more effective over longer periods. The relative savings obtained by such formulations might show even more significant results if the water had been seeded with hexadecanol-attacking bacteria.

Formulations consisting of hexadecanol and a bactericidal agent should: [1] have no significant toxicity to humans; [2] not reduce the film pressure significantly; [3] resist biological attack; and [4] resist photochemical breakdown.

No attempt has been made to evaluate the health hazard to humans resulting from inclusion of bactericidal agents in the studies of hexadecanol formulations. Such consideration is, however, essential, before the acceptance of any additive to hexadecanol for evaporation control. Moreover, the economic value of such formulations is still to be determined by comparing the savings of less frequent application of hexadecanol with the increased cost of chemical.

## Acknowledgments

The authors are indebted to Paul W. Kabler for his interest in the study, to Harold P. Clark for his work in preparing hexadecanol formulations and pellets, and to Bernard H. Kenner for identifying the hexadecanol-attacking

bacteria. The authors also wish to acknowledge the technical assistance of Joseph W. Rezek and Richard R. Wandmacher, who were temporarily employed to work on this project.

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# Design Criteria for Rapid Sand Filters

## *Panel Discussion*

*A panel discussion presented on Jul. 14, 1959, at the Annual Conference, San Francisco, Calif.*

### Review of Filter Bed Design and Methods of Washing—*John R. Baylis*

*A paper presented by John R. Baylis, Engr. of Water Purification, Dept. of Water & Sewers, Chicago, Ill.*

ABOUT 39 years ago, before all the early wooden tub filters were replaced, the author recalls having seen one after it had been used for many years. The filter had no gravel; the underdrains were of brass pipe with a series of slots cut close together. The pipe was about half embedded in cement mortar. The sand bed was about 4 ft deep. One of the wooden staves had given way near the bottom of the filter and spilled water and sand on the floor. The remaining sand was washed clear of the filter bottom for several square feet. The slotted-pipe underdrains and the lack of gravel were particularly interesting features, for after a few years of working with gravel filters, the author realized that gravel beds can be very troublesome. The wooden tub filters, however, had given excellent service for a number of years and required little maintenance.

Nowadays, when filter beds become so upset after a few years of operation that they have to be rebuilt, one cannot help recalling the long service life of the filter without gravel. Because filter plant operators are constantly beset by gravel problems, a review of filter design may be instructive.

Because filter design is a very broad subject, this article is limited largely to two items of design that have been controversial for many years. The first is the system for keeping the beds clean; the second is the filter underdrain system.

A carryover from slow sand filtration to rapid sand filtration was the belief that sand filtered best when the grains were covered with an organic film. Therefore, the first rapid sand filter designs were based on gentle washing of sand grains so that the film would not be removed.

In the past, suppliers installing filter plants had to guarantee a certain percentage of bacteria removal, usually 98 per cent. Many operators thought that sand beds full of mudballs and clogged areas filtered better than beds free of such accumulations. Inefficient bacteria removal was often attributed to areas at the bottom of the gravel bed where there was an insufficient circulation of water. This led to the construction of sloping concrete ridges or pyramids at the bottom of filters to prevent dead areas. Often these were constructed at considerable expense. They did no harm, but they did little good, except that in some of

the early plants they were used to fasten down a wire cloth screen covering the gravel.

Because of the present importance of keeping filter gravel in place, in this article more emphasis is given to early filter bottom designs with holding-down screens than would otherwise be necessary. This is not to imply that wire cloth screens should be reinstated, but that something should be done to reduce the high cost of rebuilding filter beds. A knowledge of past efforts to hold gravel in place should be helpful in any study of filters. At least, such knowledge would reveal the techniques that have failed. Fortunately, preoccupation with bacterial pockets and the necessity for maintaining an organic film around sand grains can now be abandoned.

## Early Filters

The early rapid sand filters were, for the most part, wooden tubs 8–20 ft in diameter and 7–9 ft in depth. Most of the filters were equipped with mechanical rakes. At first, much effort was made to avoid the use of gravel. The strainers often were supported on a false bottom of wood or steel about 12 in. from the bottom of the filter. The washing rates at that time were 4–8 ipm of vertical rise, which required some aid to produce effective flushing of the sediment from the beds.

When attempts were made to have water flow through brass caps with small holes, narrow slots, or wire screens in contact with sand, the openings became clogged. Sand sizes were small when filters were first used, usually 0.30–0.40 mm in effective size. If the filter openings were small enough to retain the sand, they clogged readily. If they were large enough not to clog, sand would pass through.

The Louisville experiments conducted by George W. Fuller and colleagues in 1895–97, made use of filters without gravel in the beds. Details of filter construction were left to filter companies and may not have represented an engineer's concept. The competing companies, no doubt, used what they considered their best design.

By 1900, it was realized that filters with gravel were more practical for supporting sand. Development was then centered on methods of holding the gravel in place in the bed. At first, comparatively thin layers of gravel were used, then thicker layers.

### *Designs by Engineers*

It was inevitable that consulting engineers should take over the design of filters, because most water supplies had become municipally owned, and the employment of consulting engineers for planning municipal improvements had become common practice. A few cities organized their own engineering forces for such planning, generally employing one or more engineers. Rapid sand filtration design by consulting engineers yielded some new ideas, although generally engineers were conservative and had a tendency to use designs that someone else had found practical.

*Little Falls, N.J.* The filters at Little Falls were the first ones designed by engineers along modern lines. George W. Fuller (*1*), in describing the Little Falls plant, stated: "The rectangular filter tank is made possible by the use of air agitation in place of mechanical agitation." The use of air with wash water was started in about 1900. Fuller also remarked:

> The filters are to be provided with Continental strainers, over which will be placed 6 in. of fine, screened gravel

and 30 in. of medium sand. The sand is to have an effective size within the limits of 0.35–0.42 mm, and not more than 1 per cent by weight is to be finer than 0.25 mm.

The design of this plant set the pace for the layout of filtration plants along lines now generally followed. Previously, suppliers designed filters with the idea of patenting enough new ideas and controlling the patents so that a particular design could be forced into use. Suppliers also desired to develop the kind of equipment that would be built without much assembly work. Naturally, consulting engineers objected to these ideas.

*Harrisburg, Pa.* The filters at Harrisburg were first used in 1905. The beds consisted of 7 in. of gravel and 30 in. of sand. The gravel was in two layers: the bottom layer was $\frac{1}{4}$–$\frac{3}{4}$ in. and 4 in. thick; the top layer, 12 mesh to $\frac{1}{4}$ in. and 3 in. thick. The pipe underdrains for each filter were in two equal sections. Each section had a cast-iron manifold built in the concrete floor of the filters and a series of parallel horizontal pipes with perforations on their lower sides.

From the manifold, 1¼-in. pipes rise vertically, 6 in. apart, connecting into 1¼-in. galvanized-iron T's, from the horizontal runs of which 1¼-in. galvanized-iron pipes extend either way, nearly to the sides of the filters. The pipes are capped at their free ends and have $\frac{7}{32}$-in. holes drilled along the bottom of each, 3 in. apart from center to center (*2*).

*Cincinnati.* The Cincinnati filtration plant was put in operation on Nov. 1, 1908. Inasmuch as prominent men conceived the filter design, the plant undoubtedly represented the work of the best engineering talent of the time. A lengthy description of the plant (*3*) was given by Manahan and Ellms in 1907.

Compressed air was not used, and no mechanical device was employed to agitate the sand. The filter boxes, consisting of two beds each, were 32×50 ft and 10 ft deep. There was a center gutter, 3 ft wide. Each side had six V-bottom troughs. The strainer system consisted of perforated brass plates covering channels in the concrete. A wire screen above the gravel was used to hold it down during the washing. In the bottom of each filter were 112 3.5-in. cast-iron risers from the effluent piping. These were in four rows across the filter. The individual pipes were 12 in. from center to center.

The bottom of the filter was level and made of concrete. Extending the full 50-ft length of the filter were ridges constructed of concrete: 11 in. high, 9.5 in. wide at the bottom, and 2¼ in. wide at the top (Fig. 1). The ridge centers were 12 in. apart. At 3 in. from the bottom of each ridge, a shoulder was made on each side, using curved brass plates, $\frac{1}{16}$ in. thick. The plates were perforated with 64 $\frac{3}{32}$-in. holes per linear foot. This formed 28 longitudinal rows of strainers in each filter.

In the wedge-shaped spaces above the plates were four layers of gravel, $\frac{1}{16}$ in.–1 in. in size. There were 30 in. of sand with an effective size of about 0.35 mm and a uniformity coefficient of about 1.60. The spaces between the ridges were filled with gravel, which was then covered with a 100-mesh, No. 20 brass wire cloth.

In 1909, Phillip Burgess of the Ohio Department of Health commended the operation of the plant (*4*) and stated that it was so satisfactory that to suggest any improvements, either in con-

struction or operation, would be difficult. An article in the *Engineering News-Record* of Jun. 19, 1909, describing the Vivian rate controller for the filters at Cincinnati, stated that no rate controller up to that time could be regarded as satisfactory. Although this type of rate controller did not come into general use, it was used in the Cincinnati plant for a number of years.

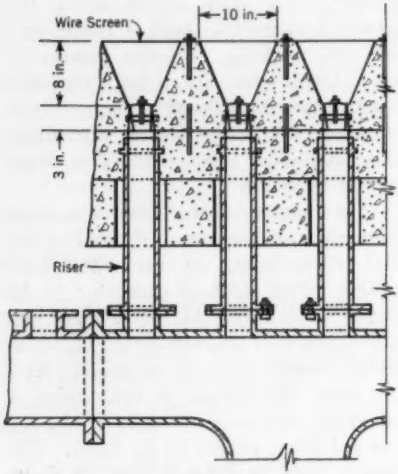


**Fig. 1. Filter Bottom With Holding-Down Screen: Cincinnati**

*This filter bottom was used in the Cincinnati filtration plant, first operated in 1908.*

*Minneapolis.* The design of the Columbia Heights plant at Minneapolis, first operated in 1913, was described (*5*) in 1911. The bottoms of the filters had a series of waterways made of parallel ridges and grooves, somewhat similar to those at Cincinnati, that were cast in concrete, 12 in. apart between centers (Fig. 2). The tops of the ridges were 13 in. above the floor. The brass strainer plates were 5 in. from the floor and formed channels that were about $2\frac{1}{2}$ in. wide and 5 in. high. Layers of graded gravel were placed over the strainer plates up to the top of the concrete ridges. A 10-mesh brass screen was placed over the gravel and fastened to the concrete ridges.

## Jet Action

The destructive action of jets in filters was early recognized. Ellms, in his book on water purification (*6*), states that "jet action is in a measure inevitable in almost any strainer system, but the more pronounced it becomes and the further up into the filter beds the jets of water are projected, the more undesirable is the effect produced." It was Ellms who coined the expression "jet action," which the author has used so often in discussing filter beds during the past 24 years. There is some difference between the early meaning of jets and the author's use of the word. Many of the early filters were equipped with pipe underdrains and strainers screwed into the pipe. Some of the strainer heads had small holes, $\frac{1}{16}$–$\frac{3}{32}$ in. in diameter; others had slots or wire cloth. The jet action was thought to originate at the strainers, even though they were under 8–12 in. of gravel. The jets referred to by the author originate in backwashing at the junction of stationary material and partly suspended material in motion. This is described in an article published in 1935 (*7*) and, more fully, in a recent article (*8*). The 1935 article states that:

> Most of the troubles occurring in filter beds start at the junction of the sand and gravel. . . . Instead of the wash water passing from coarse material not in motion into sand uniformly over the entire area, it passes into the sand in numerous places in the form of jets and at velocities many times that of the average for the entire bed.

Only some of the pertinent filtration plants will be mentioned in this article. These are the plants that appear to have had considerable influence on filter design. Other plants fully described in the literature have been omitted for the sake of brevity.

## Holding-Down Wire Cloth

Ellms (*6*) stated that screens over gravel were first used at Cincinnati and resulted from extensive hydraulic experiments undertaken prior to the design of the plant. He later said that "the life of brass wire cloth has proven to be very short with certain waters.

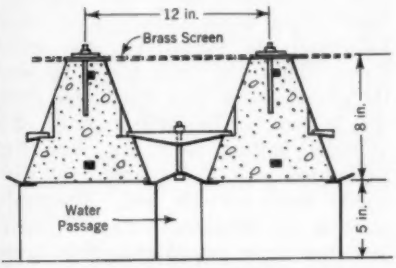


**Fig. 2. Filter Bottom With Holding-Down Screen: Minneapolis**

*This is the filter bottom used in the Columbia Heights plant at Minneapolis, first operated in 1913.*

At Cincinnati and Louisville, Ky., the brass wire cloth in the filters has corroded badly and has finally become worthless." It was further noted that the wire screens in the Grand Rapids, Mich., and New Orleans plants had not corroded.

The life of the holding-down screens was so short that by 1914 their value was questioned (*9*). With regard to the Cincinnati plants, it was said that the brass wire screens were gradually going to pieces from corrosion. Extended tests by Ellms, however, using an experimental filter and two large filters, were quite promising and indicated that a heavier and deeper gravel layer would eliminate the necessity for screens. The author believes that erosion at the jets was more responsible than corrosion for the failure of the screens.

The wire screens were removed from the Cincinnati filters in about 1915, and the depth of the gravel was increased to 14 in. The author has found that wire screens in filters have been installed in only one filtration plant (Erie, Pa., 1934) since 1915, although some of the smaller filtration plants may have used screens after this date. With the disuse of holding-down wire screens in filtration went the last hope of engineers for a means of keeping filter gravel in place.

Figures 1 and 2 show the designs of two filter beds with holding-down screens that were tried between 1907 and 1914. With the exception of filters without gravel, no filter bottom that will prevent gravel mounding has been developed, for mounding originates at the junction of material not in motion with material that is in motion when the filter is being washed. This is a fact difficult for engineers to realize.

## Filter Underdrains

A symposium on experiences with filter underdrains (*10*), published in 1914, contained comments from eight leading filtration engineers and operators. Ellms told of the difficulties experienced at the Cincinnati plant from the corrosion of holding-down screens. He thought that maintenance costs of 35, 38, and 48 cents per million gallons for 1911, 1912, and 1913, respectively, were not excessive. The imperfect method of holding the screens to the ridges, and the defective manner in which the widths of

cloth were fastened together at the edges, allowed a slight upward movement of the screens under the pressure of rising wash water, which caused them to pull apart.

Fuertes, who designed the perforated pipe underdrains for Harrisburg, discussed filter underdrains. He stated that there had been no trouble with the system; only about 2 in. of sand had been lost in the 9 years of operation. Hoover told of the difficulties at Columbus, Ohio, from the breakage of bolts that held down the strainer plates. Thick layers of gravel without holding-down screens were satisfactory at Niles, Ohio, according to Burgess. No trouble with holding-down screens had developed at Grand Rapids, according to Sperry. Weston mentioned that:

> In 1894 and 1895, more attention was being paid to the development of filter underdrains than to any other feature of mechanical filters . . . introduction of air below the gravel layer has the effect of discharging the gravel, and to overcome this tendency, either the gravel layers were greatly thickened or coarse screens were placed just above the gravel, as at Cincinnati.

Lovejoy said that the 70×30-ft filters at Louisville, Ky., had functioned very well in the 5 years of service. Holding-down screens were used. Four strainer plates had come loose in the 5-year period.

**Wheeler Bottom**

The Wheeler bottom (*10*) was first used by Weston in 1913 at Belfast, Me. This type of bottom consists of a system of inverted pyramids usually spaced about 1 ft apart. The outlet of each pyramid is about ¾ in. in diameter. Over each outlet is placed a ball, generally made of porcelain, 3 in. in diameter. Four smaller balls are placed in the four corners, and additional, smaller balls are often used. Graded gravel, 8–14 in., is then placed above the balls. This arrangement replaces the coarser gravel and avoids the use of strainers or perforated pipe. Not many Wheeler bottom filters were in use in large-size plants when Hardin (*11*) made his survey in 1930–31. The use of this type of bottom has increased since then.

The Wheeler bottom produces upflows of water over the filter through ¾-in. holes. Each upflow strikes a round ball in such a manner that the flow is divided into four, approximately equal flows. These strike other balls and are subdivided into more flows. Thus, the water passes up into the gravel and is well distributed over the bottom. The author rates the Wheeler bottom on a par with the perforated pipe in its ability to distribute water over the bed. The tendency of the Wheeler bottom to form jets that cause gravel mounding is as great as that of the perforated pipe.

The Leopold duplex filter bottom was first developed in about 1924. Built of concrete, it did not come into extensive use at that time. Later (about 1934), it consisted of blocks of hollow, vitrified tile with small orifices in the upper part of the block, the orifices discharging upwards. The hollow parts of the tile form channels for conveying the filtered water and the wash water. The larger sizes of gravel are not used; the beds of fine gravel are 6–12 in. in depth. This type of bottom produces very good distribution of the wash water and may equal the performance of the perforated pipe. A number of filter bottoms of this type have been installed in recent years. The significant fact is that regardless of how uniform the

distribution is, jet action and gravel mounding will be produced at the gravel surface.

### Porous Plates

The porous-plate * bottom, first tried at the Chicago Experimental Filtration Plant in 1935, has been installed in a number of filters. The plates are of fused crystalline aluminum oxide with a porosity close to that of fine gravel. The openings are not large enough to allow sand to pass through. No gravel is used. The plates clog too rapidly in some water to be considered practical. If the plates would maintain the same loss of head in backwashing for a considerable length of time, this bottom would eliminate the difficulty now being experienced from gravel mounding. Because there are a number of such bottoms now in use, a survey of filters equipped with porous plates would be helpful to the filter designer.

### Other Filter Bottoms

From the large number of designs that have been tried on filter bottoms, it would seem that little room is left for new ideas. Most of the many types that have been suggested are capable of distributing the wash water uniformly over the filter. Good distribution is, of course, one essential in any system. Consideration could be given to about a dozen different designs, such as the cemented-gravel layer, used in two or three plants in 1925 and 1926. This type of bottom did not prove successful. Also, there was the wooden-slat bottom developed by Armstrong (*12*). The purpose of this article, however, is not to review in detail the different types of filter bottoms. Rather, the purpose is to point out past trends in engineering attempts to find the ideal filter bottom.

* Aloxite; a product of the Carborundum Co., Perth Amboy, N.J.

### Compressed Air

Compressed air, regarded as a suitable substitute for mechanical rakes at the time the Little Falls plant was designed in 1901, was not used in the Cincinnati plant in 1907 because it was thought to be unnecessary. This, however, did not eliminate the use of compressed air, which is still used in filters and occasionally installed in a new plant. The author believes that as an aid to filter washing, the value of compressed air is quite limited.

### High-Rate Backwash

The Cincinnati plant was one of the first to use a high rate of backwash. It was the experiments by Ellms and his coworkers that hastened its use throughout the country. Washing at a rate of about 24 ipm vertical rise, instead of 8–12 ipm, seemed to be most practical. In the tabulation of filters by Hardin (*11*), very few of the larger filtration plants were noted as using rates of backwash less than 20 ipm vertical rise.

Weston (*13*), in 1917, listed four types of strainers used most extensively:

1. Manifolds, strainers, and 14 in. of gravel
2. The Harrisburg system of perforated pipe, with 14 in. of gravel
3. Troughs having strainers at their bottoms, with 14 in. of gravel
4. The Wheeler filter bottom, with 8 in. of gravel.

Weston states:

> All of these systems should be designed to wash the sand layer without the use of air. . . . Of these, No. 2, the Harrisburg system, is the simplest. . . . System No. 1, like that installed by most of the

filter companies, possesses the advantage over System No. 2, the Harrisburg system, of having the outsides of the pipes protected by concrete.

Weston was of the opinion that No. 1 and 2 left dead spaces on the floor of the filter, between the openings where the wash water does not reach. The excessive cost of No. 3 makes it inadvisable. The dead-space difficulty is overcome in No. 3 and 4. Weston further states that 30 years of experience indicates that the successful filter will be washed at a high velocity with water alone. The underdrain system should be designed to throttle the discharge of wash water from the orifices.

In 1920, an article in *Engineering News-Record* (*14*) noted: "When screens to hold down the gravel are eliminated, deeper gravel layers used, and air is replaced by a high-rate wash, any system which will provide sufficient loss of head to distribute the water evenly under the sand layer is satisfactory." The above is true today if we limit it only to the distribution of wash water. It still does not insure good washing of the sand bed. Progress in installing perforated pipe underdrains was slow at first. Such systems, however, had been installed in the filters of a few filtration plants by 1920, and all were reported to be performing well. The article further stated that the depth of gravel had been materially increased since the first thin layer at Little Falls. The depths in high-rate wash plants had been increased two or three times. Deep layers of gravel were used with perforated pipe, in which the perforations pointed downward, the idea being to obtain better distribution and less shifting. The part of the article relating to mudballs indicated that they hampered practically all rapid sand filter operation. Hand methods of breaking up or removing mudballs were used in some of the plants. Blowups sometimes occurred in the brass plates, but most plants reported no such difficulty.

Various top sand–scouring devices in use were noted in the same article:

> One naturally—and properly—turns his study to the sand surface, where most of the dirt accumulates in the first 3–6 in. . . . Experience at Oakland, Calif., with jets at the sand surface, indicated that a very small jet force only was necessary to project sand grains as well as turbidity for long distances if directed with the normal, rising current.

Various devices were used to remove partly or break up mudballs. V-shaped deflectors and sand washer ejectors were being tried. The article also mentioned that "separate water jets diverting a portion of the flow from the underdrains to the top have been suggested and used with success by the Champaign-Urbana Water Co." This article and the problems caused by filter beds that clogged, two of which are shown in Fig. 1 and 2, motivated the efforts that resulted in the development of a practical surface wash system for keeping filter beds clean.

## Surface Wash Studies

The first study of a surface wash of a rapid sand filter, as an aid to keeping the sand bed clean, was made by DeBerard and Pearse (*15*):

> In addition to the air and the high-rate water wash, experiments are being carried on with an auxiliary water wash of the surface sand. A grid of small perforated pipes is placed above the sand layer when it is at rest. During washing, the sand rises over the grid and is agitated by the jets issuing from the perforations. The amount of water used

by the grid is measured by a 2-in. Trident meter. Various combinations of water through the underdrains and grid are being tried, together with different positions of the grid with respect to the surface of the sand.

The statement appeared 51 years ago in a leading engineering magazine; although a valuable contribution, it was passed over with little notice. Another paragraph in the same article noted that the experimental filters could be washed at a rate of 3.5 fpm vertical rise. Very high backwash rates apparently were tried.

Babbitt (*16*) in 1915 stated that DeBerard, in discussing a paper presented by Talbot in 1914, suggested than the difficulties from filter bed clogging might be overcome by using an additional wash water manifold immediately above the sand layer. This was done. A year later, Amsbary (*17*) stated that after a 6-month trial in one filter, such grids were placed in all the filters. Good results were reported.

Events worked against DeBerard in his efforts to establish the use of the surface wash for filters. The panic of 1907–8 caused the experimental work at Oakland to stop before much data could be obtained. The plant of the Champaign-Urbana Water Co. was an iron-removal plant, handling well water. Prechlorination of the water was started a few years after the surface wash grids were installed. This stopped the growth of *Crenothrix* in the filter beds, which was the main cause of the clogging trouble; the surface wash then was not necessary.

### Filter Bed Cleaning

In 1924, the author published his results of studies on filter beds at Baltimore (*18*), where considerable trouble was being experienced from mudball formation, clogged areas, and disturbed gravel beds. The results of the experiments with a surface wash system were given. This system seemed to be the most promising method of keeping filter beds clean. There were ten written discussions of the published results, which were received with mixed reactions. Babbitt said that the surface wash in the filters of the Champaign-Urbana Water Co., although partly successful, required an amount of water so great as to render their use uneconomical. Burgess thought that surface washing of filter sand layers was advantageous and should be considered for use where there is clogging of sand beds by organic or other matter. Ellms remarked that the author's remedy for removing the colloidal material was certainly interesting. Daily said that St. Louis, in 1916, tried filter jets similar to those described, but the results were unsatisfactory. Donaldson, who regarded as satisfactory the method proposed for Baltimore of installing auxiliary wash jets above the sand, thought that other operators might reasonably urge that this method was not the only one. Hawley believed that the top-wash idea was excellent, and that it would save wash water and minimize cracks and mudballs. Metcalf thought that broader investigation was needed before final conclusions could be made. Waring was unconvinced that the difficulties could not be prevented by well distributed wash water at an average rate of 24 ipm vertical rise.

Mention is made only of the discussions of the surface wash. The article dealt mostly with filter bed clogging, and the discussions were related largely to this subject. There was considerable criticism of the coarse size

of recommended filter sand. The 0.6-mm size mentioned in the article was intended to be the average size of the sand in the top 16–18 in. of the bed, and not the 10 per cent effective size. Such sand most likely would have had an effective size of about 0.4 mm in diameter.

The author received a letter concerning one trial of surface wash jets in a private plant in 1926. The jets were said to have produced good results. Surface wash jets were installed in the filters of the Chicago Experimental Filtration Plant, which began operating in 1928. A description of this surface wash (*19*) was published in 1929.

The author often has wondered why it took about 10 years for engineers to begin to consider surface wash systems. Presumably they were waiting for the development of an ideal filter bottom that would solve all filter bed problems. It seems that some are still waiting.

*Sand Bed Expansion*

In 1929, Hulbert and Herring (*20*) reported the results of a study on the washing of rapid sand filters. They concluded that clean sand filters better than sand with an incrustation, and that backwash rates that expand the bed 50 per cent are better for keeping the sand clean than lower rates of backwash. This conclusion almost caused a stampede for a change-over to higher rates of backwash in existing plants, and new plant designs provided for 50 per cent sand expansion. The condition of many filter beds was improved by the higher washing rate. Most filters already had washing facilities that would allow an increase in rate. Of the thirteen engineers and filter operators who submitted written discussions of the article, there was almost unanimous agreement that this was a real step forward in the maintenance of filter beds.

Included with the author's praise of the article, was the concern that a very high rate of backwashing would disturb the gravel. This concern was the result of considerable experimentation on filter washing for a period of about 10 years prior to 1929. In his discussion, the author said:

> It is recalled in a few instances that where beds which were being washed at a high rate did become partly clogged, the gravel was disturbed by the high rate. The rate of wash suggested by the authors [Hulbert and Herring] is getting near the point where there will be movement of the fine gravel even though there is no clogging. It has not been demonstrated that a movement of the gravel will be serious if there is no clogging, yet I am of the opinion it will be. Until it can be demonstrated by long use that very high rates of wash may be used, I am not ready to recommend rates greatly in excess of the customary 24 ipm vertical rise. I believe, however, that a rate of 30 in. may be used safely.
>
> Where there is considerable tendency for the beds to clog, as is the case at a few plants, it does not seem possible that the little additional agitation due to higher suspension of the sand would produce the desired results. Sand that is just in a state of motion has almost as much scrubbing effect as if the backwash were much greater. That more force is needed than is now generally applied should be evident to almost everyone operating a rapid sand filter plant.

In 1930, Paul Hansen (*21*), in reviewing practices of water purification, stated that within the past year Hulbert and Herring had established a new concept of filter cleaning by advocating a rate of filter wash that would produce 50–60 per cent expansion of the sand bed. He stated that Baylis, who was concerned about the difficul-

ties that would result from a high rate of backwash, had proposed an auxiliary surface wash supplied by a grid of piping placed above the normal surface of the sand. Hansen said that final conclusions about the best means of washing sand filters could not be formulated at that time, but that the work of Hulbert and Herring had brought about a much better understanding of the principles of cleaning filters. He also said that there might soon be more efficient methods of washing that would do away with cracking phenomena, mudballs, and many of the other difficulties associated with filter sand. Hansen further noted that aside from a change in the practice of filter washing, there had been little significant change in the design or operation of the filters themselves. Within recent years, there has been a tendency to use coarser sand grains. The increase in effective size has been from 0.35 mm to about 0.55 mm.

After the Hulbert and Herring report had been published, the author, in 1930, again urged that wash water be applied with more force (*22*):

> For the past 6 or 7 years the writer has been advocating the solution of filter bed clogging troubles by the application of a force that will keep them in good condition almost regardless of the clogging tendency of the water. So far no one seems inclined to resort to anything other than applying the wash water underneath the beds. The work at Baltimore, and more especially the excellent work of Hulbert and Herring at Detroit, calls attention to the fact that not enough force is now being applied into the beds. The writer feels that he is on the right track with the surface wash and that something of this nature will eventually have to come into use.

This article (*22*) created no new interest in the surface wash, the slow development of which, in the light of later events, is difficult to explain. The performance of the surface wash was observed by many water utility engineers and operators at the Chicago Experimental Filtration Plant, but only one operator was sufficiently interested to try the surface wash in 1933.

### Use of Surface Wash

Surface wash pipes were installed in four of the eight filters at Kenosha, Wis., in 1933, and about 2 years later, they were installed in the other four. Good results were reported. These installations probably represent the real beginning of surface wash systems. A properly installed fixed-jet system will give good results, but, unfortunately, many such systems have been so poorly designed that at best only partial success can be expected. The rotating jet is a patented device, with which many filters have been equipped. The manufacturer tries to make certain that it is designed properly. The fixed jet is essentially a part of a low-pressure system, operating under pressures of 5–15 psi at the jets. The rotating system requires 50–100 psi of pressure at the jets.

One essential in filtration is to keep the filter beds clean; a properly designed surface wash system will do this. Fixed jets, as mentioned before, will keep filter sand in any filtration plant in clean condition, even if the clogging tendency of the water is great. Rotating jets will keep filter sand clean in most filtration plants, although fairly long periods of washing may be necessary when waters with a high clogging tendency are used. There may be some waters with which no agitation other than the backwash is needed; the author, however, does not know of any.

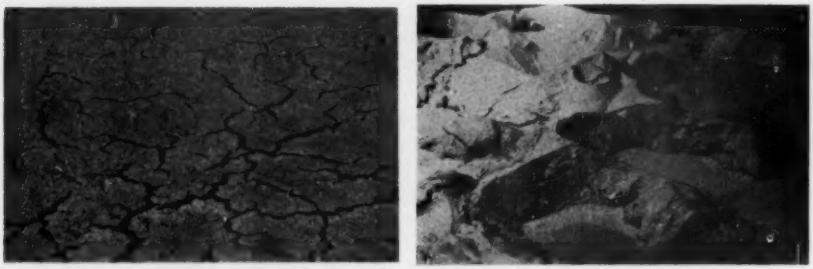

**Fig. 3. Condition of Filter Beds Before the Introduction of Surface Washing**

*Left: Cracks in the surface of a filter bed used in 1922. This filter bed shrank as the loss of head in the filter increased. Right: A badly clogged filter used in 1922. This condition was caused by a gelatinous coating around the sand grains.*

**Fig. 4. Effect of Surface Wash**

*The photograph on the left is of a filter used for 7 weeks without being surface washed. The filter on the right has been surface washed. Both photographs were taken in 1947.*

**Use of Gravel**

Because of the extensive use of gravel on the bottom of filter beds, and the probability that this use will be continued, it is important to know how to utilize gravel most advantageously.

A second essential in filtration is to keep the gravel in filter beds from moving. After about 60 years of effort, this still has not been accomplished, but there is hope. Engineers will have to stop confining their thoughts to the fixed parts of filter bottoms, such as perforated pipe, Wheeler balls, and glazed tile with small holes, and study the part of the filter in which the trouble is taking place. This is where material not in motion comes in contact with material in partial suspension and in motion. A possible means of keeping gravel in place will be described later.

**Design of Large Filter Beds**

Hardin (*11*) assembled data on 66 filtration plants in cities in the United States and Canada with populations of more than 100,000. Every filter used in these cities contained gravel. In general, there were two types of filter bottoms: those with deep beds of gravel, and those with a construction that took the place of the lower part of the gravel bed. The Wheeler bottom is an example of the latter type. With a few exceptions, the gravel layers varied in depth from 14 to 24 in.; two plants had filters with gravel depths greater than 24 in. The first filtration plant constructed in New Orleans in 1909 had filters with gravel depths of only 9 in. With other types of bottoms, such as the Wheeler bottom, 9–12 in. of gravel were used.

Since the publication of Hardin's article, the design of filter bottoms has not changed much. The Wheeler and Leopold bottoms are used extensively, and in new installations they are used as often as the perforated-pipe bottoms. Other designs of bottoms have been patented and are now used in a few filters. The author has no definite information on the number of the several types of bottoms now used. The trend seems to be toward shallower gravel layers, which are a result of substitutions for coarse gravel.

*Problems of Design Engineers*

In the 1920's, filter-design engineers were perplexed by several problems. The air and water wash was not as successful as many thought it would be, and some engineers were not using air. Filter-manufacturing companies had not given up their efforts to control filter design, even in cities where engineers had been employed to design filtration plants. In some places, the companies were offering a design of their own at a lower price.

In the latter part of the nineteenth century, a number of companies were constructing filters. Baker (*23*) points out that:

> In the 20 years after Patrick Clark and John W. Hyatt joined forces and incorporated the Newark Filtering Co. late in 1880, many filter companies sprang up, competition and patent litigation were rampant, consolidation after consolidation occurred until Jul. 25, 1900, when the New York Continental Jewell Filtration Co. stood almost alone in the field. It was heir to scores of patents. . . .

In 1912 or 1913, engineers apparently became skeptical about the value of the holding-down screen. The Minneapolis filtration plant, designed in 1911, used the screens. In 1912, the design of a large filtration plant (80 filters) for the Croton supply of

New York City allowed bids on three systems of filter bottoms; one system included holding-down screens. The Baltimore plant, designed in 1913 or 1914, did not include screens. Something must have happened between 1911 and 1913 to cause a decline in the use of holding-down screens. Perhaps, the objections of filter plant operators were beginning to be heard.

In 1913, the author was actively engaged in filtration work, helping to design and then supervising the construction of a 4-mgd plant. Threats of patent suits hampered the efforts of the engineers. The situation was further complicated by a filter manufacturer's offer of an alternate plan with a construction cost lower than that estimated by the engineers. Other filter manufacturers argued that their plans were best, even if they would result in higher costs. The type of filter bottom to be used was to be decided by the bidder, although he did have to specify the equipment. Much discussion centered on the choice of filter bottom. Should holding-down screens be used? How should the bottom be constructed so that bacteria could not find places in which to concentrate? Should air be used? Should the backwash rate be high or low? These were some of the questions that had to be answered, but, frankly, the answers were not known. The advice received was so conflicting that it confused the situation. Other engineers in other cities were in the same predicament.

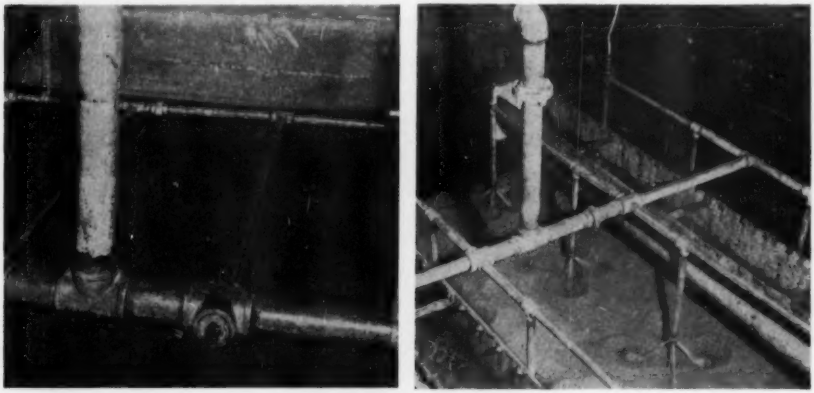

**Fig. 5. Surface Wash Systems**

*Left: First surface wash installed in the Chicago Experimental Filtration Plant in 1929. Right: Same system changed to pipes with brass nozzles (1930).*

## Past Condition of Filter Beds

New attempts to keep gravel in place in filter beds are no more effective than earlier attempts, probably because engineers have failed to become aware of the cause of the gravel movement. If the cause is known, nothing has been done to filter design to eliminate the difficulties. It is true, however, that jet action is known to be a cause, but it is not yet fully understood. Underdrain systems have been blamed for causing sand jets or boils in filter beds. Many people have been, and some still

are, of the opinion that if the right kind of underdrain system is installed, there will be no movement of gravel.

It is interesting to note the condition of filter beds before surface washing was introduced. Figure 3 shows a badly clogged filter, caused mainly by a thick, gelatinous coating around the sand grains. Such conditions usually occurred in the summer and fall. Also shown are cracks in the surface of a filter bed that shrank as the loss of head became greater. This usually occurred in the winter and early spring. To demonstrate the adhesive quality of a gelatinous coating around sand, a wooden board was pressed into the surface of a thickly coated sand bed. When the board was lifted, as much as 3 in. of sand adhered to it.

When the filters in Chicago's South District plant were first used in 1947, the surface wash system had not been completed. One of the photographs in Fig. 4 shows the condition of a filter used for 7 weeks without being surface washed. A large number of mudballs were found on the surface. Figure 4 also shows the surface of a filter that was surface washed. It is apparent that the surface-washed filter is in better condition.

### Fixed-Jet Surface Wash

That the surface wash is functioning well in keeping filters clean is shown in Fig. 5. One photograph shows the first system installed in 1928 in the 10×10-ft filters of the Chicago Experimental Filtration Plant. This system worked very well, except that the holes drilled in the $\frac{3}{4}$-in. galvanized pipe eroded and became larger. Also, sand sometimes got inside the pipe and clogged some of the holes. The system was changed in 1930 to pipes with brass nozzles (Fig. 5), the use of which has been very successful. Even after 11 years, they show practically no signs of wear. If the holes are drilled properly to avoid sand abrasion, the nozzles may be expected to last for a considerable length of time. Plastic nozzles, however, may be substituted for the brass ones.

### Gravel Replacement

Materials with specific gravities greater than that of gravel were tried in filter beds. Within a short period of service, all materials utilized showed signs of movement.

*Black Grit (sp gr 2.90–3.00)*

The black grit used was the melted flue dust from a high-pressure steam-generating plant. A 6-in. layer of this material, consisting mainly of $\frac{1}{12}$–$\frac{1}{8}$-in. pieces of grit, was placed over $\frac{1}{4}$–$\frac{1}{2}$-in. particles of gravel. When the filter was washed to produce an 8-in. bed expansion, there was some movement of the grit, and soon the layer was as uneven as might be expected of gravel alone.

A 6-in. layer of black grit was added to a filter after the sand and the two top layers of gravel had been removed. The sand was then replaced and the filter put back in operation in 1955. The bed is now off level in places, but not as much as some of the other filter beds in the plant.

*Crushed Iron Ore (sp gr 3.30)*

A layer of crushed iron ore was tried in 1957. The filter bed was constructed with gravel layers as in the large filters, except for the $\frac{1}{12}$–$\frac{1}{8}$-in. and the $\frac{1}{8}$–$\frac{1}{4}$-in. layers. Crushed iron oxide of these sizes was then added and 24 in. of sand replaced. The bed was soon off level by 6 in. or more.

*Aluminum Oxide Pellets (sp gr 4.0)*

Another high specific gravity material tested was aluminum pellets. An 8-in. layer of pellets with diameters of $\frac{1}{8}$–$\frac{1}{2}$ in. was put in a filter with a glass side. Figure 6 (top left) shows part of the filter after one light backwash, which made the sand move a little. The white material in the sand is the aluminum oxide.

After eight backwashes in 7 days, the bed of aluminum oxide was as shown in the top-right portion of Fig. 6. Very likely there was not much expansion of the material, and the height above the original level was mainly along the front edge. Jet action along the glass side was more active than along the other walls of the filter. Some $\frac{1}{12}$–$\frac{1}{8}$-in. gravel that was with the sand mixed with the aluminum oxide and showed up as dark spots in part of the oxide layer.

Figure 6 (bottom left) shows this same filter 7 months later. The upper part of the oxide layer had been moved by jet action during backwashing. After 3 months of additional use, the aluminum oxide layer was a little more off level (bottom right).

The specific gravity of aluminum oxide was approximately 4.0 at the start and about 3.4 at the end of the test. The cause of this decrease may have been the result of a partial coating of aluminum oxide particles with lighter material. The disturbance of the oxide layer had not extended downward more than $3\frac{1}{2}$ in. in 9 months. Even if a disturbance does not go deeper, there still would be extensive mounding in a large filter bed.

When the sand was siphoned from the filter with the backwash turned on, the aluminum oxide was seen to be mounded around the side walls of the

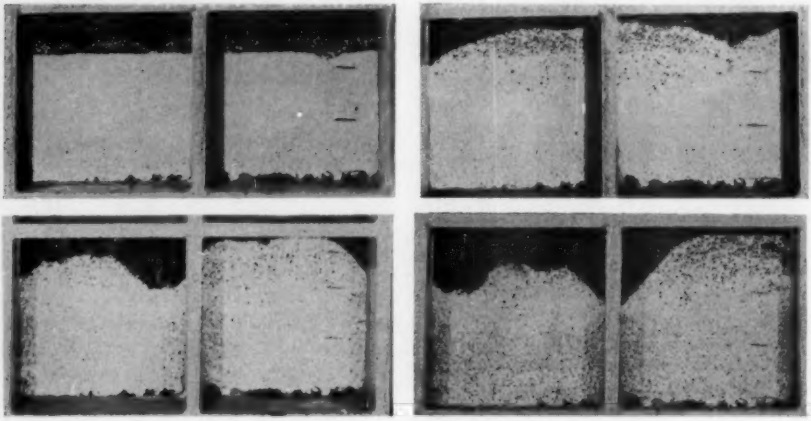

**Fig. 6. Aluminum Oxide Layers in Glass-Side Filter**

*Top left: The oxide layer, after one, light backwash, is practically level. Top right: After eight backwashes in 7 days, the oxide layer has begun to show mounding. Bottom left: After 7 months of service, the upper part of the layer shows a considerable degree of mounding. Bottom right: After 10 months of service, the disturbance of the oxide layer has extended downward.*

filter, with the center of the bed being about 2 in. lower than its original level. Although aluminum oxide may be better than gravel because it is not so easily moved, it still cannot be regarded as satisfactory.

## New Filter Bed

The author's studies of filter beds during the past 30 years lead to one conclusion: *the gravel must be kept where it is placed in the bed.* For this purpose, some kind of holding-down device for gravel must be used. Present opinion is against the brass-wire cloth screen as it was used years ago (Fig. 1 and 2). These screens have proved to be impractical, for the cost of repairing them may exceed that of rebuilding filter beds once every few years. And because filter beds can be rebuilt without high costs, filters have been kept in fair condition. Therefore, it may be advocated that the cost of rebuilding filters should be accepted as a normal operating expense. This is just the thing that has been done for the past 60 years. Not only is this procedure expensive in the long run, but it also involves the short-term correction of a bad condition that will be bad again.

### *Rearrangement of Gravel*

Since the early part of 1959, experiments have been conducted with a new arrangement of the gravel layers in a filter (Fig. 7). The gravel bed is at first built up from coarse to fine layers as usual, except that some of the layers are shallower. After the layer of smallest gravel is installed, layers of coarser gravel are placed over it. Pieces of gravel with diameters less than $\frac{1}{8}$ in. are not used. The first layer of gravel placed over the $\frac{1}{8}$–$\frac{1}{4}$-in. layer consists of $\frac{1}{4}$–$\frac{1}{2}$-in. particles. The next layer consists of $\frac{1}{2}$–1-in. gravel, and the top layer is 1–2-in. gravel. The changes in size of the upper gravel layers are in reverse order of the lower layers, when the $\frac{1}{8}$–$\frac{1}{4}$-in. layer is considered as median. The coarser gravel layers at the top serve as holding-down material for the finest gravel size.

The first experiments on a rearrangement of gravel layers were conducted with a 6.5-in. plastic tube filter in January 1959. In this filter only backwash tests were run. The next tests, begun in February 1959, were done with a glass-side filter. Settled water, the same as that going to all of the large filters, was used. Figure 8 (left) shows part of the filter, which was backwashed at a rate to give about 25 per cent bed expansion. The gravel bed was constructed with a 3-in. layer of $\frac{1}{8}$–$\frac{1}{4}$-in. gravel as the middle gravel layer. On top of this was a $1\frac{1}{2}$-in. layer of $\frac{1}{4}$–$\frac{1}{2}$-in. gravel. The next layer was also $1\frac{1}{2}$ in. thick, composed of $\frac{1}{2}$–$\frac{3}{4}$-in. gravel. The topmost layer was 3 in. thick, composed of $\frac{3}{4}$–$1\frac{1}{2}$-in. gravel. Figure 8 (right) shows part of this filter after 2 months of operation in a manner similar to that for the large filters. The filter is equipped with a rate controller and loss-of-head gage. It can be fed with

TABLE 1

*Grading of Gravel in the Plant Size Filter*

| Gravel Layer* | Depth of Layer *in.* | Gravel Size *in.* |
|---|---|---|
| 1 | 4 | $1\frac{1}{2}$–$3\frac{1}{2}$ |
| 2 | 3 | $\frac{3}{4}$–$1\frac{1}{2}$ |
| 3 | 2 | $\frac{1}{2}$–$\frac{3}{4}$ |
| 4 | 2 | $\frac{1}{4}$–$\frac{1}{2}$ |
| 5 | 4 | $\frac{1}{8}$–$\frac{1}{4}$ |
| 6 | 2 | $\frac{1}{4}$–$\frac{1}{2}$ |
| 7 | 2 | $\frac{1}{2}$–1 |
| 8 | 5 | 1–2 |

* No. 1 is the bottom layer of gravel; No. 8 the top. No. 5 is the layer of finest gravel.

water from either of two settling basins, or from both.

All of the sand and gravel was removed from a plant size filter, and the bed reconstructed in accordance with the new plan of gravel arrangement. The decision to make a test on a plant size filter was not made until 4 in. of the 1½–3½-in. gravel had been placed in the filter. The results of a short operation of the glass-side filter justified the trial of a large filter. Table 1 shows data on the grading of gravel.

The depth of the sand, measured from the bottom of the eighth layer of gravel, was 24 in. The new grading, as shown in Fig. 7, would have 4 in. of 1–2-in. gravel for the bottom layer, but there would be a larger stone along each side of the filter underdrain to keep the gravel from getting directly underneath an opening.

*Precautions in Washing*

Figure 9 shows the effects of backwashing in the plastic tube filter. Washing rates up to those producing more than 150 per cent bed expansion were tried. With the bed at rest, the voids in the 1–2-in. gravel were filled with sand; some sand settled into the layer of ½–1-in. gravel. The voids in the 1–2-in. layer were so large that they formed passageways that allowed

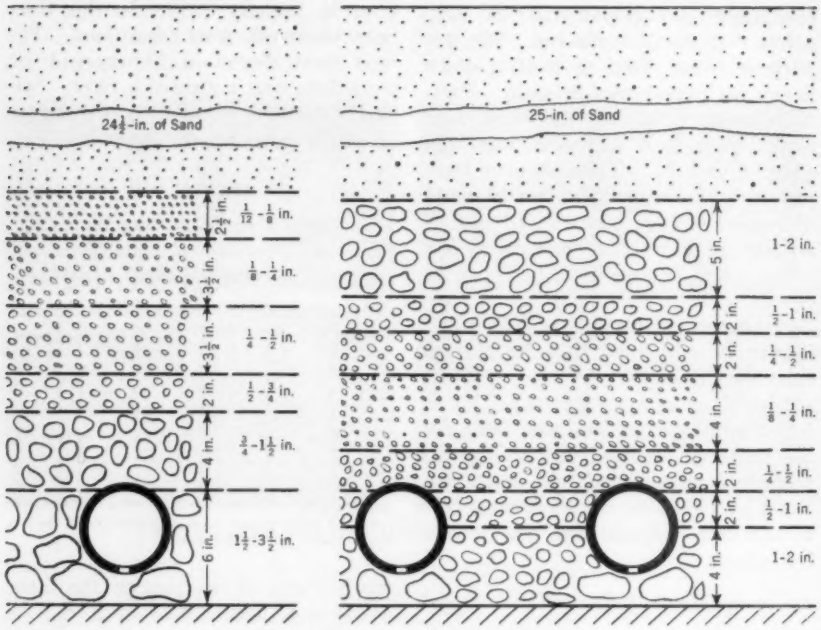


**Fig. 7. Gravel Depths in Filter Beds**

*The left portion of the figure shows the layers of gravel in the beds of Chicago filters. On the right is a newly designed filter bed. The large circles in the bottom layers of the beds represent the filter underdrains.*

sand jets to extend through to the ½–1-in. gravel. A very high rate of backwash, about 12 fpm vertical rise, was required to wash nearly all of the sand above the larger gravel particles. At this very high rate, there was no movement of any of the particles of gravel. Inasmuch as such a high rate of backwash would never be used, it is safe to assume that the gravel could not be disturbed in washing, except by a backwash with enough force to lift the bed.

flow is required to start expanding the bed, usually a rate of 5–7 gpm/sq ft of filter when the sand is 0.5 mm in effective size. Sand beds do not expand from the bottom upward, but from the top downward. The bed may be lifted before expansion takes place, producing a layer of water between the sand and gravel, with almost no sand in the water layer if there is a too rapid turn-on of the backwash. After the sand bed is lifted 1–3 in. or more, the water breaks through the sand at

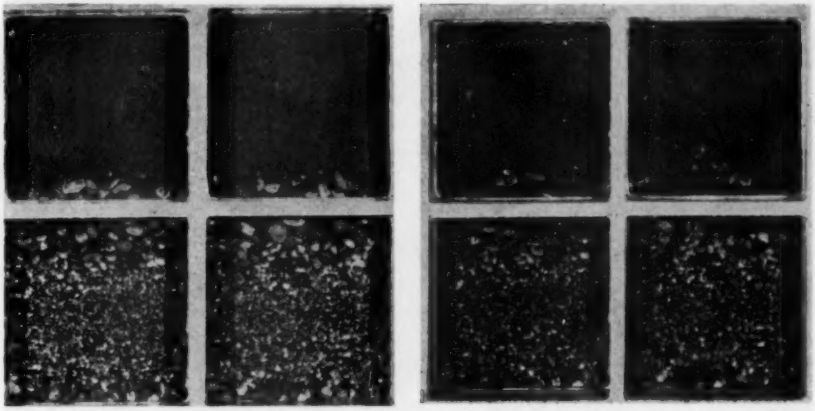

**Fig. 8. Gravel Layers in Glass-Side Filter**

*The illustrations show a filter bed reconstructed to conform to the new arrangement for gravel. On the left, the filter is being backwashed to give about 25 per cent bed expansion. On the right is the same filter being backwashed after 2 months of operation.*

Enough force can be produced in a rapid turn-on of backwash to lift this bed, just as it will lift the bed of any sand filter. The most damage to sand and gravel filters results when water is allowed to drain entirely from the filter and then the backwash is rapidly turned on. Under these conditions, enormous boils are produced when the water first breaks through the surface. When water is first applied underneath a sand bed, a certain rate of

various places and produces large boils. In the new gravel arrangement, with sand filling the voids in the 5-in. layer of top gravel, this layer would be lifted with the sand and most likely would produce a gradual shifting of the gravel.

Not much extra force is required to float sand beds, and there always is a sufficient wash water head to do this. Water naturally can escape quite freely through the big voids in large

gravel, but if the voids are filled with sand, the water reacts as though the mixed layers were all sand. Until part of this sand is washed out from between the gravel particles, as the sand bed expands, the bottom of the coarse gravel will act as the bottom of the sand bed. Although the sand between the gravel is greatly expanded in Fig. 8 (right), a considerable amount settles back in some places and is forced upward in other places as jets.

It is known from experience that not much sand settles into the layer of ½–1-in. gravel (Fig. 8, left). During filtration, there is a tendency for the sand to flow deeper into the gravel. No sand has been observed in the ¼–½-in. gravel, although a small amount quite probably does settle there.

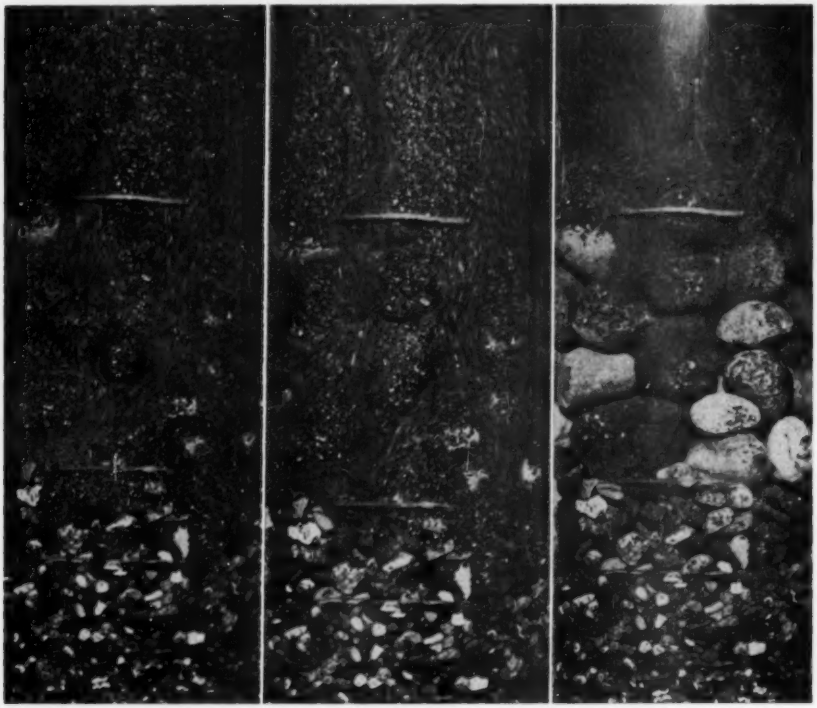

**Fig. 9. Effects of Backwashing in the Plastic Tube Filter**

*On the left, the filter is being backwashed at a rate to produce 25 per cent bed expansion. The center illustration shows backwashing to produce 50 per cent bed expansion. On the right, the same filter is being backwashed at a rate of about 12 fpm vertical rise. The illustrations show the upper layers of gravel.*

*Jet Action–Resistant Gravel*

The gravel specified for the new filter bed is of a size that cannot be moved by jets that originate in it. It is known that ¼–½-in. gravel can be moved by jets likely to develop in almost any sand bed. Jets of consid-

erable size are able to move ½–1-in. gravel; jets in sand boils (jets that extend through the sand bed) can do the same. One aim of the new filter bed arrangement, therefore, is to prevent large sand boils.

It has been observed in filter backwashing that the larger the size of gravel used, the larger will be the jets that form. There appears to be no possibility, however, of a jet being formed that will move gravel of greater than 1-in. size if the sand mixture is fluid.

Experiments were carried out on gravel particles of various sizes to determine their rate of fall through water. For gravel with a diameter of 1 in., the rate averaged 2.1 fps; ½-in. particles of gravel fell at a rate of 1.5 fps. The size of the plastic tube containing the water may have had a great effect on the rate of fall of large particles.

The backwash rate of flow required to wash practically all sand from 1–2-in. gravel was approximately 12 fpm vertical rise. As mentioned before, this rate caused no gravel movement in any part of the bed. It should also be noted that this rate of vertical rise approaches the rate of fall of sand through water, which varied from 0.2–0.4 fps for the size of sand used in the Chicago filters.

### *Further Precautions*

The author warns filter operators to proceed cautiously before changing over to the new grading of gravel. Only one or two newly graded filters should be tried for 1 year or more before other units are regraded. Operators must also refrain from turning on the backwash too rapidly.

### *Operation of Plant Filter*

The Chicago South District Filtration Plant has dial gages in the filter galleries that show the rate of backwash. The operating instructions for one of the filters with new grading calls for the controlled opening of the backwash valve so that about 60 sec are required for the backwash rate to increase from 5 mgd to 20 mgd. A backwash rate of 30 mgd is equivalent to 24 ipm vertical rise. With a $\frac{3}{64}$-in. orifice plate in the pressure line to the hydraulic cylinder that operates the 30-in. butterfly backwash valve, and with a pressure of 100 psi on the line, the increase in backwash rate comes close to the 60 sec desired for the rate increase. Electrical control of valve operation probably would be better than the present hydraulic control.

This filter has functioned satisfactorily since the gravel was regraded. No difficulty from gravel movement is anticipated. There is, however, a possible source of trouble from coagulated material that may gradually clog the ⅛–¼-in. gravel, but a long period of operation will be required to determine whether this will occur. The filter is set to take in water at a constant rate of 3 gpm/sq ft of filter surface, and periodic checks of the rate of flow and loss of head indicate that the unit is well controlled.

If the new gravel grading works, one of its attractive features is that it requires no modification of most filter boxes, for the new grading is simply a rearrangement of filtering materials already in use. The time to install the new grading is when a filter bed is rebuilt.

## Summary

1. The early operation of rapid sand filters was marked by many difficulties, among them the clogging of filter beds and the mounding of gravel.

2. At one time, the cause of the difficulties of filter operation was at-

tributed to poor distribution of the wash water.

3. Attempts to prevent the movement of gravel by the use of wire holding-down screens were not successful.

4. A surface wash system was developed to prevent mudball formation and clogged areas. When properly designed and operated, such a system is an effective aid to cleaning.

5. Attempts to eliminate mounding in filter beds by replacing gravel with materials of higher specific gravity were unsuccessful and costly.

6. A modification of gravel grading in filter beds has been effective in small experimental units.

7. In the South District Filtration Plant, one large filter equipped with regraded gravel has been used since Jun. 11, 1959.

## Acknowledgment

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# Declining-Rate Filtration—*Herbert E. Hudson Jr.*

*A paper presented by Herbert E. Hudson Jr., Partner, Hazen & Sawyer, New York, N.Y.*

The goal of the filter plant designer is the production of high-quality water at all times. Another of his important aims is to keep costs of construction and operation low. Sometimes the achievement of both these ends is not possible, and an undesirable compromise has to be accepted.

Traditionally, American filter plants control filter operation by constant-rate devices. This traditional approach sometimes falls short of the production of high-quality water, particularly with the higher filtration rates and coarser sands used in recent practice. For the design of the Wayne County, Mich., filter plant, a critical examination of filter rate control led to a year-long study that compared a simple declining-rate system * with traditional constant-rate control. The results of this study were applied to the plant design. Design theory indicated that a declining-rate system would produce better water, and the experiments to be described were arranged to check this. The tests consisted of parallel operation of a conventional constant-rate filter and a filter whose rate controller had been replaced with a fixed orifice.

Although both filters produced good quality water at the same average filtration rates, the filter with the declining rate produced water with 27 per cent less suspended matter than that in the water produced by the constant-rate filter during periods of breakthroughs due to weak flocculation. When there were no terminal breakthroughs, the declining-rate unit produced water that was 20 per cent clearer than that from the constant-rate unit. The filter runs for the declining-rate unit averaged 30 hr, or 37 per cent longer runs than the average for the constant-rate filter. Wash water requirements were accordingly reduced.

The idea of making the filter run itself is not new. It is widely practiced in industrial filtration and has been used in some municipal installations. For example, the Howard Bend filtration plant at St. Louis was operated successfully along these lines for 6 months in 1949. Subsequently, the St. Louis County Water Co. central plant was expanded to operate at filter rates that declined and that were limited by controllers to a fixed maximum rate. Under certain conditions, old plants with inoperative rate controllers function well on declining filter rates.

## Breakthrough Index

Two types of breakthroughs occur in rapid sand filters: initial and terminal (*1*). The initial breakthrough is usually brief and of low magnitude, adding less than 5 per cent suspended matter to that passing the filter in one run. This article is concerned solely with the terminal breakthrough, which sometimes increases suspended matter in the filtrate by tenfold or more. A terminal breakthrough consists of a continually increasing passage of suspended matter through the sand into the clear well. In ordinary practice, the filter produces water with about 0.1 ppm suspended matter, but under severe breakthrough conditions this

* The term "variable rate" has been used to describe this system. "Declining rate" was suggested by R. L. McNamee as being the more descriptive name.

concentration may exceed 1 ppm, and sometimes even 10 ppm.

The frequency and extent of breakthroughs are functions of floc strength or, rather, of floc fragility. The floc strength in the applied water can be expressed, by the "breakthrough index" ($K$),* in terms of the filtering conditions under which the terminal breakthroughs begin:

$$K = \frac{Vd^3H}{L}$$

in which $d$ is the effective size of the sand in millimeters; $L$ is the bed thickness in feet; and $V$ is the filtration rate in gallons per minute per square foot and $H$ the loss of head in feet at the time the breakthrough begins. The derivation of this index and a table of values for various plant conditions are given elsewhere (*2*). Values of $K$ as low as 0.5 are experienced in many plants during weak floc periods. This means that with usual filtration design, breakthroughs must be expected at times. When the breakthrough index drops to 0.5 in a plant using a filter rate of 2 gpm/sq ft and 0.5-mm sand in beds 2 ft thick, then filtered water quality begins to deteriorate when the head loss reaches 4 ft.

Although, in usual practice, $K$ exceeds 3 most of the time, filter design should be based on the most extreme conditions expected. With constant-rate operation, $V$, $d$, and $L$ are constant, and the expression $\frac{Vd^3H}{L}$ increases throughout the filter run. By causing $V$ to decline as $H$ increases, $\frac{Vd^3H}{L}$ can be held below any limit desired. If the plant is designed to keep $\frac{Vd^3H}{L}$ from exceeding the lowest expected breakthrough index for a particular water, then the filters can be allowed to operate at any rate desired, without fear of water quality impairment.

Manipulation of filter rates below the limiting $K$ value can be managed by using the clear-well level as a back pressure against the filters. This is easily arranged in new plants and frequently can be adapted to old ones. Where this is not possible, the positioning of filter effluent valves by master control will suffice.

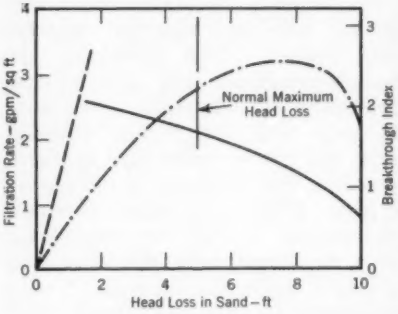


**Fig. 10. Relationship of Filtration Rate and Breakthrough Index to Head Loss—Wyandotte Filter**

*The solid curve indicates the filter rate as clogging proceeds; the dashed curve, the filtration rate with clean sand. The dashed and dotted curve represents the breakthrough index. This declining-rate filter had a 4.8-in. orifice.*

With a declining rate, the filter bed removes more suspended matter per filter run than can be removed by constant-rate operation. Suppose the system is designed to cause the filtration rate to decline from 3 gpm/sq ft at the beginning of the run to 1 gpm/sq ft at an 8-ft loss of head. The

* Formerly denoted as "filtrability index." The change in terminology has been made to retain the meaning of filtrability index as a measure of the filter-clogging characteristic of water.

average filter rate is about 2 gpm/sq ft, but the permeability of the bed at the end of the run is the same as that which would have occurred in a filter running at 2 gpm/sq ft at a head loss of 16 ft. The use of declining rates should therefore produce longer filter runs, even when a plant is operated to yield an average filtration rate equal to that maintained in a plant with conventional constant-rate control.

The adverse effect of surging on filtered-water quality has recently been discussed by Baylis (*3*). He showed that surge amplitude was proportional to the square of the flow rate. The declining-rate system, by cutting down surging toward the end of the filter run, is expected to improve water quality at that time.

### Wyandotte Test Program

Declining-rate and constant-rate operations were compared from August 1957 to September 1958 in the 10-mgd Wyandotte, Mich., filtration plant. In this plant, all filter beds are maintained in excellent condition, and filtered-water turbidity during the test period, as measured by the cotton plug method, averaged 0.096 ppm. No coagulant aids were used. The test procedure was reviewed and approved by the Michigan State Department of Health before the tests started.

The Wyandotte tests included the operation of two 1-mgd filters at filtration rates of approximately 2.4 gpm/sq ft. One filter continued to operate with its conventional constant-rate controller. The rate controller was removed from the other filter and replaced with a fixed orifice, sized to produce a declining filtration rate that would produce an average rate equal to that of the constant-rate unit. At the start of the filter run, the filtration rate was 2.7 gpm/sq ft. It slowed to 2.1 gpm/sq ft when the head loss reached 5 ft. The filters were washed at this head loss in accordance with standard Wyandotte practice and were operated all year at these rates.

The filter sand was coarser than that usually used, effective sizes being in the range of 0.7–0.8 mm. As the tests proceeded, the data indicated that one filter had finer sand than the other. Accordingly, the control equipment was interchanged between the two filters to equalize test conditions.

Under the conditions of the Wyandotte tests, $\frac{Vd^3H}{L}$ varied during declining-rate runs (Fig. 10), attaining a value of 2.2 at a 5-ft head loss. Had the filter operated to higher head losses, $\frac{Vd^3H}{L}$ would have risen to a maximum of 2.5 at a head loss equal to two-thirds of the 11-ft total available head.

Filtered-water quality was evaluated from the concentration of suspended matter left in the water. Bacterial efficiencies could not be used, for prechlorination completely eliminated coliform organisms at all times, as shown by 728 samples analyzed by dilution and membrane filter techniques. Suspended material was measured by turbidimeters, cotton plug filters, and a recording microphotometer.* The cotton plug filter device for measuring the concentration of suspended material in the filter effluent proved to be very reliable. It gave consistent results and reflected accurately the changes in operating conditions. The cotton plug filter used in the Wyandotte tests was accurate within limits of about ±0.01 ppm; it was sensitive to concentrations as low as 0.001 ppm. The recording

* A product of the American Instrument Co., Silver Springs, Md.

microphotometer proved to be just as reliable and gave a detailed, moment-to-moment record of water quality changes.

### Terminal Breakthroughs

Figure 11 shows examples of breakthroughs at the ends of the filter runs on two occasions in February 1958. With only one microphotometer available, it was not possible to obtain records from both filters under identical conditions. Although the two runs plotted are nearly comparable, there were differences in the quality of the applied water. The breakthrough

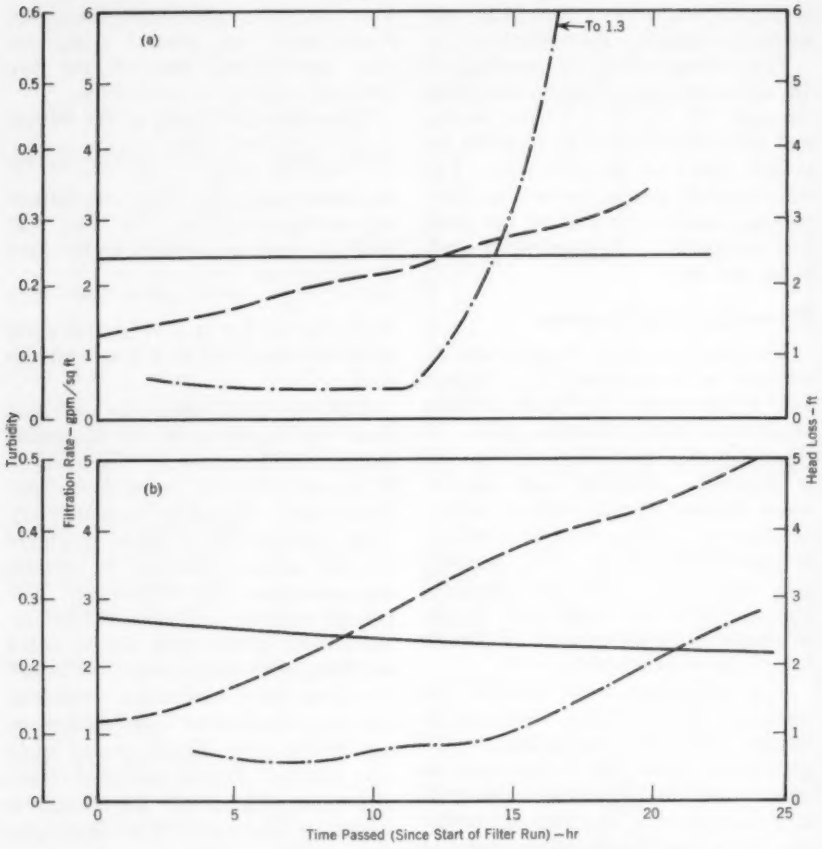


**Fig. 11. Typical Filter Runs During a Period of Weak Flocculation—Wyandotte Filtration Plant**

*Part a shows the curves for the constant-rate filter; Part b, the curves for the declining-rate filter. The solid curves represent the filtration rate; the dashed curves, the head loss; and the dashed and dotted curves, the filtered-water turbidity.*

index for each of these runs was about 1.6, and on the two occasions the test filters were deliberately operated well beyond the point at which breakthrough began. Figure 11a shows the loss of head, filtration rate, and turbidity data for the constant-rate unit. At the end of this run, the turbidity of the constant-rate filter effluent was 1.3.*

Figure 11b shows corresponding data for the declining-rate unit. It will be noted that the breakthrough was not prevented altogether, but the turbidity rise was smaller. In Fig. 12, the filtered-water turbidities from Fig. 11 have been replotted against values of $\frac{Vd^3H}{L}$ calculated from the filter rates and head losses in Fig 11. Both curves show continued production of good-quality water until a critical value of the breakthrough index is reached. This is followed by a sharp rise in suspended matter as $\frac{Vd^3H}{L}$ increases further. The rise was generally steeper for the constant-rate unit than for the declining-rate unit.

The breakthrough index was checked daily throughout the test period. For this study, the beginning of the breakthrough was defined as the time that filtered-water turbidity rose above 0.2. The weakest flocculation occurred in early January 1958, when severe contamination by minerals and other matter affected the Lake St. Clair and Detroit River waters, and all the filter plants using these sources. Figure 13 shows the individual runs for the test filters during this period of extremely weak flocculation. The beginnings of the breakthroughs were determined by filter effluent grab samples; consequently, the determination of breakthrough points was less accurate than was later possible with the microphotometer. On January 6 and 7, it was necessary to wash filters at head losses as low as 2.5 ft to keep filtered-

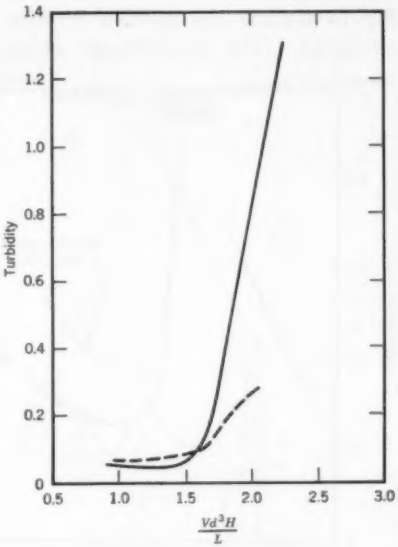


**Fig. 12. Breakthroughs During a Period of Weak Flocculation—Wyandotte Filtration Plant**

*The solid curve represents the constant-rate filter; the dashed curve, the declining-rate filter. Turbidity values, and filter rates and head losses used to calculate* $\frac{Vd^3H}{L}$, *are those shown in Fig. 11.*

water turbidity less than 1.0. The trend line in Fig. 13 indicates the rapid onset of weak flocculation and its gradual die-away. The minimum breakthrough index on this occasion was 0.6.

Breakthrough indexes for the first 3 months of 1958 are shown in Fig. 14.

* When turbidity is measured by a turbidimeter, it is expressed in arbitrary units. When measured by cotton plug filters, it is expressed in parts per million.

The open triangles and circles represent ends of filter runs during which no breakthroughs occurred; the solid symbols show the values of $\frac{Vd^3H}{L}$ at which breakthroughs started. Under the test conditions, breakthrough indexes greater than about 3.5 could not be measured, so that the curves in Fig. 14 describe only the most extreme conditions. The breakthrough index

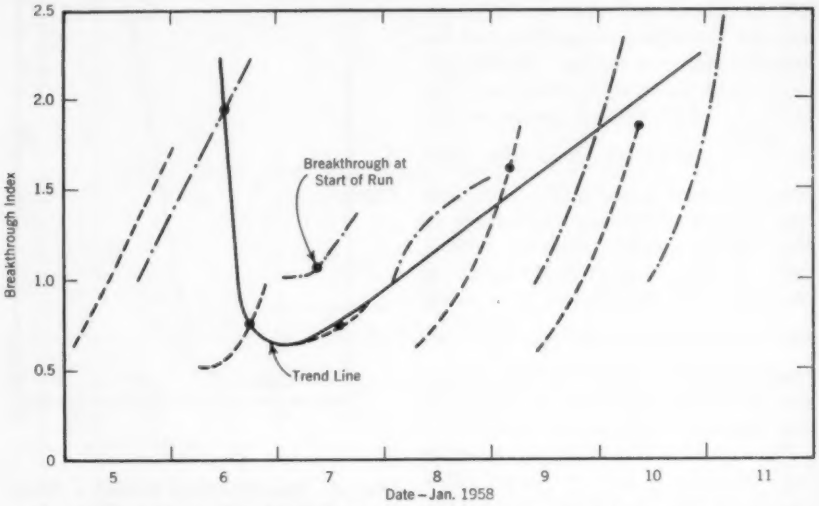


**Fig. 13. Record of a Period of Weak Flocculation—Wyandotte Filtration Plant**

*The dashed curves represent the record of the declining-rate filter; the dashed and dotted curves, the constant-rate filter. Filled circles indicate breakthroughs.*

value was greater than the values given in the open symbols.

Figure 14 also shows the turbidity, as measured by cotton plug filters. This generally increased during periods of weak flocculation. During the January 1958 incident, turbidity reached high levels on the test units, which, though backwashed at low head losses, continued operating at high rates.

**Surge Effects**

Baylis' publication on surges (*3*) is a very complete exposition of the knowledge available in this field. Surging, as it applies to filters, is observed as a pressure fluctuation. If a piezometer is connected to the outlet piping of a filter, between the filter bed and the rate controller, the water level is seen to fluctuate rapidly and erratically. Because the head loss through the filter bed is directly proportional to the rate of flow, the surges reflect momentary fluctuations in the filtration rate. These fluctuations are equal to the ratio of surge amplitude to head loss.

At Chicago, surging is controlled by the use of long-form venturi tubes in the rate controllers. Tests at Chicago had established that the surges were caused by boundary separation phe-

nomena. These could originate at any high-velocity zone, such as a throttled valve, but generally they were traceable to flow separation in the short-tube venturi meters used in rate controllers. The long-form venturis minimized these boundary separations. The magnitude of surging in the South District plant has not been accurately determined. It is assumed to be unusually small, however, less than 1 per cent.

Surge amplitudes determined by visual recording at Wyandotte are given in Fig. 15. A few filter runs were carried to head losses of more than 5 ft in order to extend the surge curves. In the constant-rate filter, the filtration rate fluctuations at greater head losses were about 0.9 per cent.

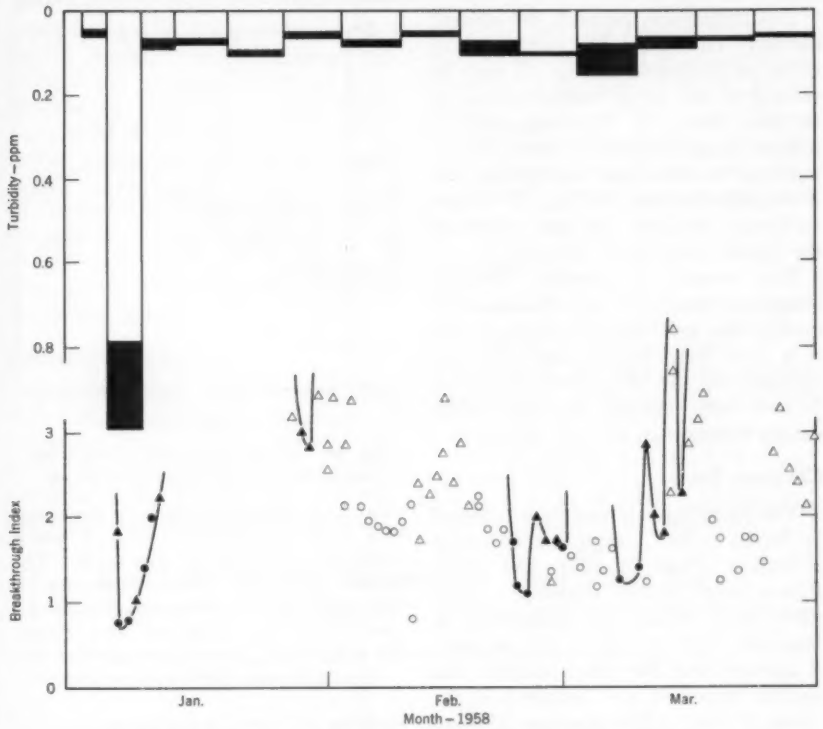


**Fig. 14. Chronologic Record of Periods of Weak Flocculation—Wyandotte Filtration Plant**

*The open bars at the top of the illustration indicate turbidity values for the declining-rate filter, as measured by cotton plug filters. The solid bars indicate constant-rate filter turbidities. The filled circles and triangles represent values of the breakthrough index at the start of breakthroughs; open circles and triangles represent ends of filter runs during which no breakthroughs occurred. Triangles are for the constant-rate filter; circles are for the declining-rate filter.*

In the other unit, they were greater than 0.9 per cent at head losses less than 3 ft, and fell to 0.67 per cent at a 5-ft head loss. Total available head at Wyandotte required unusually high orifice velocities, and the orifice was close to upstream and downstream bends. In a new design, much can be done to control these factors with a corresponding reduction in surge amplitude.

The differences between the effluent turbidity curves for the two types of units, as illustrated in Fig. 12, may be related to the surge characteristics of the two filters. If it is assumed that filtered-water turbidity is directly proportional to flow rate fluctuation, and if the turbidity data in Fig. 12 are accordingly adjusted, the two curves in the figure very nearly coincide.

The exact relationship between surge and amplitude and filtered-water quality has not been established, but it is clear from Baylis' data (*3*), and indicated by the Wyandotte tests, that filtered-water quality improves when surges decrease.

## Chicago Tests

The declining-rate system was tested by Baylis in the Chicago South District Filtration Plant in 1958 and 1959. Filters with locked controllers were used (*4*). When the differences in filtration rates are taken into account, it appears that the water quality was neither improved nor impaired in the Chicago tests. The duration of filter runs was increased more than 50 per cent by the use of declining rates, and production per filter run was proportionately increased. Although several episodes of weak flocculation occurred during the Wyandotte tests, none occurred at Chicago, where weak flocculation is prevented by activated-silica treatment, and where excellent facilities for flocculation and settling are available.

Except for surge and floc strength effects, the tests at Wyandotte and Chicago were substantially the same. Although data to prove it are lacking, it is believed that the 20 per cent year-round improvement in water quality at Wyandotte was the result of the reduction in surges, and that the additional 7 per cent improvement during

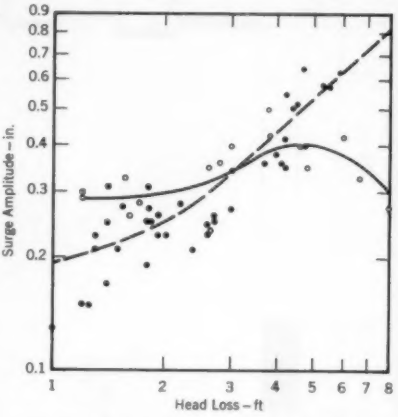


**Fig. 15. Surge Amplitude in Test Filters—Wyandotte Filtration Plant**

*The solid curve represents the declining-rate filter, the filtration rate of which varied from 1.5 to 2.7 gpm/sq ft. The dashed curve is for the constant-rate filter, which had a filtration rate of 2.4 gpm/sq ft. The filled and open circles are data plots for the constant-rate and declining-rate filters, respectively.*

periods of weak flocculation was the result of the reduction of breakthroughs brought about by the declining rate. In both plants, filter runs were more than 37 per cent longer with the declining-rate method.

## Summary

There is a limit that should not be exceeded in rapid sand filter design.

This limit is established by the strength of the floc in the water applied to the filters and can be expressed in terms of the lowest breakthrough index to be encountered. Filters designed to meet this criterion prevent breakthroughs of suspended material under the most extreme conditions.

At Wyandotte, a year's trial of a declining-rate system designed to reduce breakthroughs yielded a higher-quality water than did conventional rate control, and produced longer filter runs. Similar tests at Chicago did not produce an improvement in water quality, but filter runs were increased more than 50 per cent.

The differences between the results of the Chicago and Wyandotte tests are believed to be the result of breakthrough prevention at Chicago by use of activated silica, and of differences between the filter surge characteristics in the two plants.

**Acknowledgment**

The Wyandotte tests were done under the immediate supervision of Superintendent George Hazey, formerly chief operator of the Wyandotte filtration plant. For him and his staff, the tests involved much extra work; it was carried out with accuracy and enthusiasm. Carl Bufe, director of Wyandotte utilities, gave wholehearted support.

Hazen and Sawyer, Engineers, instituted and guided this program as part of their responsibility for functional design of the Wayne County filtration plant for the Wayne County Road Commission. The plant, for which detailed plans were prepared by Giffels and Rosetti, Detroit, was designed to meet the limiting criteria developed by the tests. Particularly appreciated is the help of A. T. Kunze, sanitary engineer for the Wayne County Road Commission, who authorized the work and arranged for the acquisition of the special equipment required.

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## Enclosed Gravity Filters and Deep Filter Beds

*Richard R. Kennedy*

*A paper presented by Richard R. Kennedy, Partner, Kennedy Engineers, San Francisco, Calif.*

The enclosed gravity filter or Australian filter design * has been used in Australia since the mid-1930's (Table 2). A personal inspection of several of these installations during the spring of 1957 is the basis of this discussion, which includes some comments on the use of deep filter beds in improving filter operation.

* Designed by the Filtration & Water Softening Pty. Ltd., Melbourne, Australia.

**Enclosed Gravity Filters**

The distinguishing features of the enclosed gravity filter are the multiple, interconnected cells controlled by one main distribution valve and one filter rate control with a common collec-

TABLE 2

*Data on Australian Filter Plants Using Enclosed Gravity Filters*

| Item | Location of Plant | | | | | |
|---|---|---|---|---|---|---|
| | Penrith, N.S.W. | Wagga Wagga, Victoria | Wagga Wagga, Victoria | Mulwala, N.S.W. | Blayney, N.S.W. | Shepparton, Victoria |
| Year constructed | 1949 | 1939 | 1950 | 1943 | 1953 | 1956 |
| Capacity—*mgd* | | | | | | |
| nominal | 1.43 | 5.09 | 5.15 | 3.73 | 1.43 | 3.72 |
| peak | | | 6.90 | | | 4.50 |
| Filters | | | | | | |
| No. of filters | 2 | 2 | 2 | 2 | 2 | 2 |
| No. of cells per filter | 8 | 12 | 8 | 8 | 8 | 8 |
| area per cell—*sq ft* | 39 | 75.6 | 100 | 68 | 39 | 81 |
| area per filter—*sq ft* | 312 | 908 | 800 | 544 | 312 | 648 |
| height of filter—*ft* | 7 | 7.25 | 7.25 | 7 | 7 | 7 |
| available filter head—*ft* | 15 | 16.5 | 16.5 | 16.75 | 15 | 13 |
| Filtration rate—*gpm/sq ft* | | | | | | |
| nominal | 1.60 | 1.96 | 2.25 | 2.40 | 1.60 | 2.00 |
| peak | | | 3.00 | | | 2.42 |
| backwashing* | 2.68 | 1.71 | 2.68 | 2.68 | 2.68 | 2.68 |
| Backwash | | | | | | |
| rate—*gpm/sq ft* | 18.75 | 18.75 | 18.75 | 18.75 | 18.75 | 18.75 |
| vertical rise—*ipm* | 30 | 30 | 30 | 30 | 30 | 30 |
| water used—% | 2.2 | 2.1 | 1.0 | 4.6 | 1.5 | 1.7 |
| head loss—*ft* | | | | 8.25 | 4.5 | 5.3 |
| head available—*ft* | 19 | 22 | | 23 | 24.5 | 18.5 |
| Settled-water pipe | | | | | | |
| diameter, to filter—*in.* | 8 | 10 | 12 | 12 | 8 | 12 |
| diameter, to cell—*in.* | 8 | 8 | 12 | 10 | 8 | 10 |
| water velocity, to filter—*fps* | 3.20 | 3.60 | 3.80 | 3.60 | 3.20 | 3.70 |
| water velocity, to cell—*fps* | 0.40 | 1.00 | 0.80 | 0.65 | 0.40 | 0.70 |
| Master control valve | | | | | | |
| No. per filter | 1 | 2 | 2 | 1 | 1 | 1 |
| type | 8-way | 6-way | 4-way | 8-way | 8-way | 8-way |
| diameter inlet × ports—*in.* | 8×8 | 10×8 | 12×12 | 12×10 | 8×8 | 12×10 |
| Filtered-water pipe | | | | | | |
| diameter—*in.* | 8 | 12 | 12 | 12 | 8 | 12 |
| water velocity—*fps* | 3.20 | 5.00 | 5.10 | 3.75 | 3.20 | 3.75 |
| meter† | SV | FN | FN | FN | FN | FN |
| control valve† | B | B | B | B | B | B |
| Collection pipe to clear well | | | | | | |
| diameter—*in.* | 15 | 18 | 18 | 15 | 15 | 18 |
| water velocity—*fps* | 1.85 | 4.40 | 4.50 | 4.70 | 1.85 | 3.20 |
| Wash water pipe | | | | | | |
| diameter—*in.* | 8 | 10 | 12 | 12 | 8 | 12 |
| water velocity—*fps* | 4.60 | 5.70 | 5.40 | 3.60 | 4.60 | 4.40 |
| meter† | VNW | O | VNW | VNW | VNW | VNW |
| control valve† | F | F | F | F | F | F |
| size—*in.* | 8 | 8 | 10 | 10 | 8 | 10 |
| Distance below top of clear well—*ft* | | | | | | |
| filter top | 13.50 | 14.25 | 14.25 | 16.00 | 17.50 | 10.25 |
| filter bottom | 20.50 | 21.50 | 21.50 | 23.00 | 24.50 | 17.25 |
| clear well inlet | 15.00 | 16.50 | 16.50 | 16.75 | 15.00 | 13.00 |
| wash water weir | 19.00 | 22.00 | | | 24.50 | 18.50 |

* Filtration rate through cells supplying water for backwash of one cell.

† Key: SV, short venturi; FN, flow nozzle; B, butterfly; VNW, V-notch weir; O, orifice; and F, float.

tion underdrainage system. Backwash is accomplished as a single-cell operation, with other cells furnishing the backwash water.

The enclosed gravity filter is a part of a water treatment plant that has hydraulic-design loadings very similar to those used in American practice. The usual Australian water supply is very similar to that encountered in the western part of the United States, where there are long periods of dry weather and where the major supply is from streams originating from winter snow packs in mountainous areas. During the rainy season or periods of high flow from the melting snows, the waters are very turbid. During the rest of the year, there may be small amounts of suspended mineral matter; however, the seasonal increase in temperature induces active algal growths in the water. A treatment plant in these circumstances generally uses water from a stream whose flow is maintained by upstream storage. The water first flows into a pretreatment basin and is then passed through filters and into clear-well storage for distribution to the customer. The features of Australian filter design that are giving excellent results under these conditions could therefore be applied in certain parts of the United States.

The main distribution selector valve is the key feature of the equipment in this filter. The valve receives the raw water and, by proper port arrangement, distributes it to pipes leading to each of the cells. One valve connection is for backwash to waste. During operation, the valve, which is rotated by an electric motor, allows backwash water from the top of any cell to go to the waste water receptacle. During its rotation cycle, the valve also causes each cell in turn to be backwashed while continuous filtration goes on in the other cells. During backwash cycles, flow is supplied by the operating cells, thus obviating expensive backwash pumps or storage.

Individual cells are constructed as equal-sided squares. They may be made of steel in small units or of common wall concrete in larger units. The underdrain system has large plenum channels that are interconnected to each cell within the group. Above the channels is an extremely simple distribution header covering the floor with a bed of conventionally graded rock and sand filter media. In these underdrains, backwash head loss of 0.8 ft is far less than the usual 15-ft loss. Each cell roof above the top of the sand is constructed in the shape of a truncated pyramid of a size to be completely filled by sand expanded 50 per cent. The entrance of the pipe connecting the filter cell to the master valve is located behind a baffle plate in the roof of the filter. Each filter has an open vent pipe carried above the level of the sedimentation tank to avoid air entrainment or siphon action. A single rate-of-flow controller regulates the discharge of treated water from the large plenum channel underneath the sand beds.

A single filter group may consist of four, six, or eight cells, the number and size of cells depending on the requirements of a project. The usual filter-loading rate of 2 gpm/sq ft has been used as the criterion for the design of public water supplies. In order to get high backwash rates, present practice is to use eight cells in a group, so that when one cell is being backwashed the water available for backwashing will be seven times the flow through a filter. Present practice also limits the size of individual cells to 10 sq ft and to a four-cell master valve for the larger sizes. Thus, an eight-cell unit

would generally require two master valves operating in a cycle.

*Operation Cycle*

During normal filter operations, the master valve is opened to supply raw water to the top of all the filters. The filtered water is removed through the rate controller, located at any convenient spot in the underdrain plenum channel. The backwash cycle is usually started when the loss of head through the filter reaches a predetermined maximum level. Then the effluent valve is closed, and the motorized master control valve is started. This action shuts off the supply of raw water to the top of the first filter cell and gradually opens a connection from the top of the filter to the waste water pipe. The water from the remaining cells travels through the interconnected bottom channels to expand the sand and backwash. Although initial installations provided surface wash, this was later found to be unnecessary. The head available for operation is determined by the water level in the pretreatment sedimentation tank. Control of backwash rate is at the outlet of the waste pipe. With the set rotation speed of the master control valve, the backwash of cell No. 1 is carried out for a period of time. Then, cell No. 2 is backwashed, while No. 1 goes back to filtering. In this manner, each cell is backwashed in turn during a backwash cycle. The valve controls are so arranged that the first cell washed is rewashed at the end of each cycle—that is, there are nine backwashes for an eight-cell unit. Thus, the cycle starts with a new filter cell each time and is normally timed for completion in 45 min.

The top of the filter sand bed is 14–16 ft below the weir elevation of the sedimentation tank. The discharge into the clear well is at an elevation above the sand surface, so that the sand bed and control valves are under a positive head at all times. The waste discharge line is usually carried below the bottom of the filter bed, so that 4–6 ft of additional head may be available for backwashing.

Some operational advantages should be noted:

1. The motorized master control valve with a preset cycle of operation lends itself to full automation of the filter unit. Actuation of the backwash can be by loss of head, quantity of flow, or on a time-clock basis.

2. Placing the filter sand so that it is under a positive head allows immediate change from filtering to backwash without any disruption of the filter bed, malfunctioning of backwash distribution, or air entrainment.

3. The reduced area immediately above the sand bed causes the velocity of water scouring to be doubled. The high velocity of water keeps the sand clean and free of mudballs.

4. The relatively small volume between the top of the filter cell and sand bed allows backwashing with a small quantity of water; an average of 1–5 per cent of the water treated is used for backwashing.

5. With interconnected, cellular filter units, backwashing is accomplished without backwash storage or backwash pumping installations.

6. Raw water cannot get into treated water, except through the sand bed. Thus, health department objections to the possibility of improper valve operation and leakage through common concrete walls are eliminated.

On the other hand, these filters have the following disadvantages:

1. Filters are enclosed; therefore the condition of the sand bed is not visible to the operator.

2. With interconnected cells, if one unit functions poorly, the other units have to make up for it.

3. With the use of a master control valve, the control of all plant functions depends on one mechanical unit. If this unit fails, the plant cannot operate.

4. The size of present units allows a plant capacity of 2.5 mgd. Plants of larger capacity require multiple units.

### Deep Filter Beds

A few American filtration plants built in recent years have used deep filter beds. With these beds, the depth of water above the top of the sand is sufficient to insure that a positive hydraulic head exists in the filter bed and effluent piping at all times, including when there are conditions of maximum design rate of flow and head loss through the filter. Deep filter beds were installed in the newly completed Bon Tempe water filtration plant, designed for the Marin Municipal Water District, San Rafael, Calif. In this plant, sand is continuously under a positive head while the filter is operating; positive head eliminates air binding in the sand, gravel, or underdrain system, or in the filter rate-of-flow controller.

Although filter operation at Bon Tempe is not completely automatic, it is believed that, with the use of deep filter beds, the plant can be operated automatically, because a change from filtering to backwash can be made immediately, without an indeterminate wait for the release of binding air. And although the nominal rate of operation is 2 gpm/sq ft, the hydraulic design is such that up to 4 gpm/sq ft may be handled by the filters without the possibility of negative head developing. There will be no loss of head from air binding in the sand or underdrains. The depth of water above the filters is 10 ft, but the cost of constructing deep filter sidewalls is believed to be offset by the improvement in filter operation.

## Valve-Operating Devices and Rate-of-Flow Controllers—*William W. Aultman*

*A paper presented by William W. Aultman, Vice-Pres., James M. Montgomery; Cons. Engr., Pasadena, Calif.*

This discussion concerns: [1] the different types of operating devices used for opening and closing filter valves and sluice gates, and [2] the means of controlling the rate of flow of water though filters.

### Valve-Operating Devices

In the past, most of the valves installed in gravity-type rapid sand filters were gate valves, with sluice gates often used on large filters in the drain lines. Today, gate valves are rapidly being replaced by perfected, rubber-seated butterfly valves, which have the following advantages: they are suitable for use as throttling or control valves; they require less maintenance and have a shorter laying length than gate valves; and they are easy to operate.

For many years the various valves—gate or butterfly—and sluice gates used on gravity-type rapid sand filters have generally been operated manually or by means of hydraulic cylinders. The fluid used in the hydraulic cylinders has been: [1] water from the regular plant supply, if available at sufficient pressure; [2] water from an open-end hydropneumatic system; or

[3] water or oil from a closed hydropneumatic system. Water from the regular plant supply or from an open-end hydropneumatic system has been used satisfactorily when it was of good quality and neither corrosive nor incrustant. Questionable waters should be used in a closed hydropneumatic system, in which they can be treated with soluble oil, chemicals, or by other means to eliminate or reduce corrosion and incrustation. Although some filter plants have been designed to use oil as hydraulic fluid, the use of oil is often objectionable because it may leak into water and because, when it leaks, it is messy and discolors concrete.

Valves operated by electric motors have been used for many years—not extensively in municipal filtration plants, however, because of the difficulty of maintaining electrical equipment in a moist atmosphere and because of the cost of the equipment. As a result of recent developments in electrical insulation, equipment is more moisture resistant than it was, but the cost of electric-motor operators is still higher than that of hydraulic-cylinder operators. In some instances, the increased cost may be justified, particularly where completely flexible, programmed operation is desired.

Several recently designed large plants are including, or have included, valves operated by electric motors. In order to permit programmed filter washing on an automatic or semi-automatic basis, two of the largest plants now in the design stage—the 960-mgd Chicago Central District Filtration Plant and the 200-mgd extension of the F. E. Weymouth Memorial Softening and Filtration Plant of the Metropolitan Water District of Southern California—are planning to use electric motors for some or all of their filter valves and sluice gates. The Chicago plant will use the motors only for those valves located within the dehumidified section of the plant. Hydraulic cylinders will be used for the other valves and sluice gates. The Metropolitan Water District will use electric motors on all filter valves and sluice gates normally operated during filter operation and washing.

Some filter plants use air cylinders to operate the valves. Two installations of this type are in northern California. The Bon Tempe Filtration Plant of the Marin Municipal Water District, which has recently begun operation and may have already been inspected, has air cylinders to control the filter valves. A nearby plant of the North Marin County Water District also uses air cylinders for this purpose. This plant has been in operation for several years, and the valve operators are reported to give good, trouble-free service.

Air cylinders were used for these two plants because: [1] the filter valves are located outside the buildings in an area sometimes subject to freezing temperatures; [2] the system is clean, with no dripping, corrosion, or incrustation; and [3] the power required is about the same as for a comparable hydraulic system, because the pumping of air or water would be required in either case. There is a question of whether the compressible air permits the sensitive control possible with the relatively noncompressible fluids in hydraulic cylinders, or with electric motors. This lack of sensitive control would probably not be a serious problem with butterfly valves, but could present operating problems with gate valves or sluice gates. Lack of sensitive control might permit the leaves of valves to become tightly wedged in their seats and therefore difficult to unseat on opening. It

is probable that because of the cost factor and the possibility of more sensitive control, hydraulic-cylinder valve operators will continue to be used most extensively in the design of new filters.

The methods of control for the valve operators described may be actuated by any of the following: [1] direct mechanical connection to the control valve or switch, [2] pneumatic control devices from a central board or table, or [3] electrical control.

### Rate-of-Flow Controllers

The use of venturi-type rate-of-flow controllers for filters has been almost standard practice for many years. A number of engineers have been considering other ways to control the flow rates through a filter. Some are planning to operate filters without the use of conventional rate-of-flow controllers. In the new 960-mgd Chicago plant, consideration is being given to the use of rate controllers on only one or two filters in a group of six, with the remaining four or five filters set to operate at a set, uniform rate.

Several plants have been designed to provide uniform distribution of flow between filters by means of an overflow weir on the influent channel, with a throttling valve on the filter effluent line controlled by the water level in the filter. One such plant, in operation for about 2 years, was constructed by the city of Oneonta, N.Y. Another plant with this design, which is shortly to go out for bids, is the new 40-mgd Miramar Water Filtration Plant of San Diego, Calif. In this plant, the variable flow in the main plant influent pipeline from the San Diego Aqueduct will be distributed equally to all the filters in service by means of an overflow weir along the filter inlet conduit. The water will not drop directly onto the sand in the filter but will enter a forebay connected by a butterfly valve to the filter box. The desired water level within the filter will be maintained by means of a butterfly valve in the filter effluent line. The valve will be controlled by a float on the surface of the water in the filter. This system is less expensive to construct, and should require less maintenance.

Where it is economically feasible to provide a filter box of sufficient depth to accommodate the total depth of water above the sand at maximum head loss conditions, rate control by valves has been eliminated completely. This has been done by carrying the filter effluent line to a height above the top of the filter sand, with free discharge being provided. If there are several filters in a plant, it is necessary with this design to distribute the flow between filters by a weir or orifice.

This type of design has been used satisfactorily for almost a year in the filters added to the Seaward Avenue Water Softening Plant of Ventura, Calif. The design of this plant was based on the use of a 37-ft diameter, 32-ft high steel tank for the aeration and contact basin, necessitated by topography and the existing hydraulic gradient. The filters were constructed of two similar 33-ft diameter steel tanks, also 32 ft high. An overflow weir on the discharge line from the filters maintains the desired minimum depth of water over the filter sand and the desired hydraulic gradient to the cation-exchange softeners.

### Recommendation

Although there is a definite trend toward complete automation of plant operations, a concerted effort should be made to eliminate, as much as possible, the complicated mechanical equipment within a plant—without adding to the work load of the operator.

# Surface Washing of Rapid Sand Filters

**Pieter C. Lindenbergh**

*A contribution to the Journal by Pieter C. Lindenbergh, Director of Water Works, Leyden, The Netherlands.*

FORMERLY, the Leyden Dune Water Co. encountered periodic difficulties with its rapid sand filters, especially in the spring and fall when a thick layer of sludge, consisting mainly of algae and plant remains, formed on the surfaces of filter beds. When the filters were backwashed with water and air, part of this material penetrated into the beds, causing clogging and, ultimately, short-circuiting. As a result, treated water did not always measure up to the company's standards.

### Past Procedures

At the time, this difficulty could be overcome only by removing the entire filter bed, washing it, and replacing it —a time-consuming effort that caused undesirable delays in filtration. Before 1951, a somewhat primitive method of surface washing was adopted in an attempt to solve the problem. Prior to backwashing, the layer of sludge on the filter bed was broken up by means of high-pressure, hand-directed jets of water. At the same time, a moderate flow of water was directed upward through the bed. This method, although not entirely unsuccessful, was costly, both in time and labor. Moreover, the entire surface of the bed was not always uniformly washed.

In 1951, an automatically moving surface-wash installation was devised. This was, however, unsuccessful, for the rather complicated structure of the gutters prevented it from working properly. The installation was ultimately replaced by a stationary one of the type used in Chicago.

### Present Procedures

In 1956, when the capacity of the rapid filters had to be doubled, a specially designed, automatically moving surface-wash installation was constructed for the new filters. It consists of two horizontal 3-in. pipes, suspended from a motor-driven vehicle that rides on the longitudinal walls of the filter tanks (Fig. 1). In each of these pipes, which are 5 cm above the filter bed, there are two rows of nozzles that are 3 mm in diameter and 5 cm apart. At an angle of about 22½ deg, these nozzles direct high-pressure water jets on the filter bed.

During the washing operation, a carefully regulated upward flow of water through the filter bed is maintained. Thus, the layer of sludge is lifted from the filter bed and broken up by the jets. The minced material floats in the water above the filter bed and is subsequently removed by backwashing. Water jets should not be directed vertically but at an angle, in

order to prevent the sludge from being driven into the filter bed.

The distance between the two 3-in. nozzled pipes is half the length of the filter bed (Fig. 2). The vehicle, therefore, need travel only half the length of the filter bed for the water jets to cover the entire surface. This feature also makes it possible to get enough water under sufficient pres-

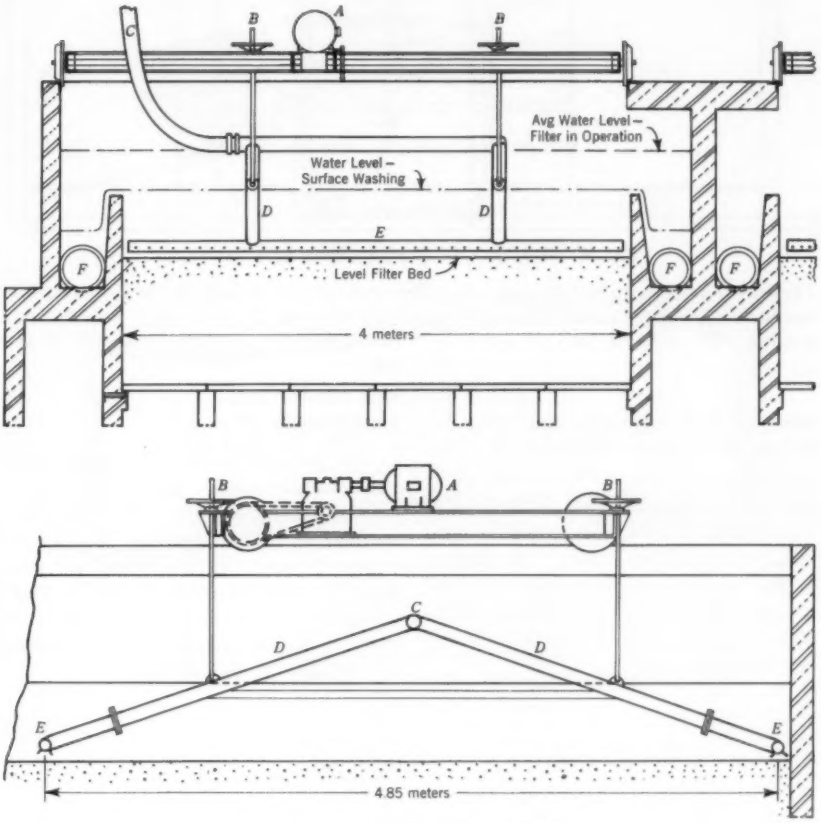


**Fig. 1. Surface-Wash Installation**

*The top diagram shows a transverse cross section of the installation and filter. The letters designate the following:* A, *motor mounted on vehicle;* B, *height-adjusting mechanism;* C, *4-in. rubber hose connected to 4-in. pipe;* D, *3-in. pipe;* E, *3-in. nozzled pipe; and* F, *wash-water removal pipe. The installation should be imagined as moving toward, then away from, the reader. The bottom diagram shows a longitudinal cross section of the installation, which should be imagined as moving from right to left, then back again.*

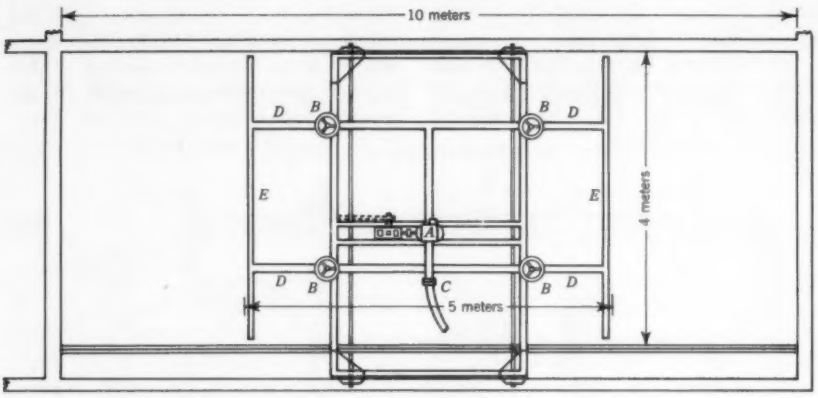


**Fig. 2. Top View of Surface-Wash Installation**

*The letters designate the following:* A, *motor mounted on vehicle;* B, *height-adjusting mechanism;* C, *4-in. rubber hose connected to 4-in. pipe;* D, *3-in. pipe; and* E, *3-in. nozzled pipe. The distance between the nozzled pipes is one-half the length of the filter bed.*

sure to the moving installation by means of a 4-in. rubber hose, connected at one end to the service pipes and at the other end to the installation. The electricity for the motor is supplied by a rubber cable. The height of the nozzled pipes can be adjusted to keep the optimum distance between pipes and filter bed, if the level of the bed changes.

## Conclusion

The new, rapid filters equipped with this surface-wash installation have been used since 1956. To date, this method of surface washing has maintained a perfectly flat filter bed, free from the penetration of sludge or other material. High rates of filtration—3 gpm/sq ft and higher—do not harm the quality of the effluent.

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*LAST WEEK'S WATER?*

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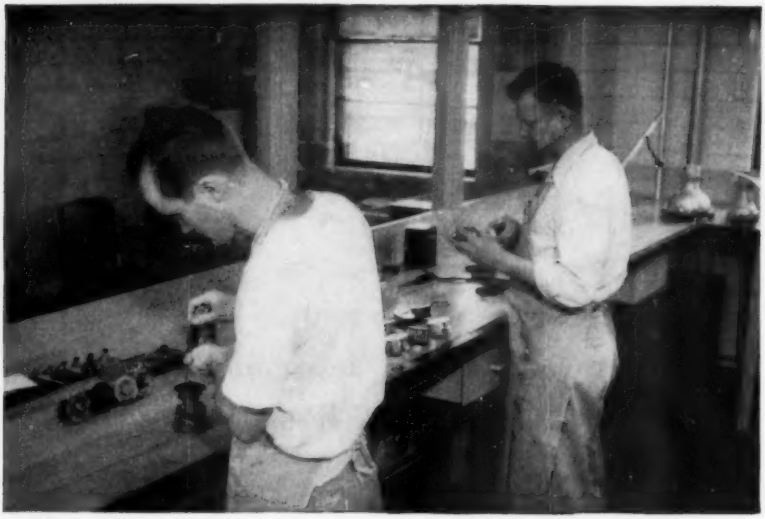

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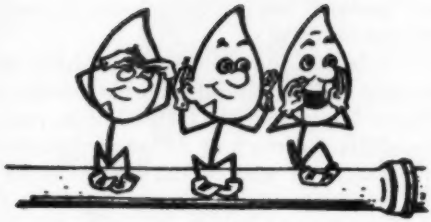

# Percolation and Runoff

**A drinking man's filter** is what we would have to label the new 0.75-gpm "Steri-Pore Drinking Water Filter," while more to a soaking man's taste would be the "Aqua-Pure Water Filter," which does its work at normal flow rates. The "Steri-Pore," says Filtros, Inc., of East Rochester, N.Y., "was designed for use on a separate cold water line, so that only water will be filtered that is to be used for drinking, cooking, or other uses where absolute purity is required." Its claim to remove all waterborne bacteria is based on the "special silver impregnation of the filter unit," which is said to "sterilize" the water passing through it. For the "Aqua-Pure," on the other hand, the Cuno Engineering Corp. of Meriden, Conn., claims only that it removes "dirt, glop, and gunk," pointing out that its product is not a water softener or treatment device, but is intended solely "to make water cleaner" by filtration through a replaceable cartridge of cellulose fibers.

But virtually 20,000 filters has a householder to choose among these days to protect his drinking as well as his smoking. Within a very few days last month we were apprised of the "Ogden Water Purifier" (Ogden Filter Co., Inc., Los Angeles), the "Sepco Ultra-Violet Water Sterilizer" (Sepco Corp., Pottstown, Pa.), and the "Steri-flo Ultra Violet Water Sterilizer" (Steri-flo Corp., Waldwick, N.J.), but there have been innumerable others too, some understandable, some fantastic, but almost all trying to capitalize on the enlightenment of the public concerning the importance of a safe water supply. The "Ogden" device, for instance, "uses a replaceable filter pack, chemically treated with bactericidal additives" not only to destroy harmful bacteria, but to "remove chlorine and offensive tastes and odors" as well. The "Sepco," by "irradiating water with powerful ultraviolet rays, . . . assures 100 per cent destruction of dangerous bacteria." And the "Steri-flo" is "guaranteed to kill 100 per cent bacteria in heavily polluted water."

That at least not all of the devices offered are living up to their claims was suggested in the February issue of *Consumers Bulletin*, which cited a California Dept. of Health investigation of the use of a commercial ultraviolet sterilizer "to convert canal water that was not intended for human consumption into potable water." They

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said it couldn't be done, of course, even though the equipment purchased for the purpose cost approximately $700.

Most of the filter fanciers are, without doubt, families who own their own water systems and are anxious to avail themselves of the same benefits that those served by public water systems obtain. But among them, too, are too many of our own customers—customers who have been frightened into doubting the safety of their supply because they have not been properly educated by their water utilities, as well as customers who have real reason to want to improve their supply because their utilities are not providing a quality product. It is these filter prospects whom we must protect, not only by education, but by performance, for, actually, it's what's up front that counts!

**Discovered** is how we felt this month when, after 38 years of occupancy, The Leadite Co. gave up its lease on our fourth cover. Recovered almost immediately were we when Johns-Manville picked up an option of 20 years' standing to fill the vacancy, but nevertheless a little nostalgic about having been so "jointed for permanence with Leadite" that the JOURNAL has since 1921 been recognizable either end up. In welcoming J-M, though, we look forward to coverage that will be transLeadite—as a matter of fact, even Transite!

**Water, water everywhere** seems to be hard to get these days. Not as hard to get, certainly, as MIT Professor A. T. Ippen suggested in telling the International Hydraulic Association in Montreal that "the world is approaching the end of its available water supplies," but, nevertheless, a problem that is both hydraulic and international:

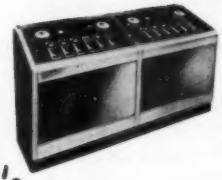
In Italy, for instance, a landslide at the end of July cut the main aqueduct to Naples and left 800,000 of its residents and much of its industry waterless for a week. And before service was restored by a temporary line, a considerable amount of heat had been generated, not only by the summer sun, but by citizens who were indignant about the $80,000,000 of tax money their government had poured into a new aqueduct that lay idle and unfinished because of regional political squabbles.

In Asia, through the efforts of World Bank President Eugene Black, India and Pakistan finally reached agreement on certain basic basic principles upon which a formula for dividing the waters of the Indus can be worked out.

Meanwhile, a somewhat smaller, though no less urgent, water problem yielded to the efforts of authorities at Gujranwala, Pakistan, who were faced with the problem of raising funds for building sanitary water supplies in 50 villages in the district to make their 600,000 children eligible for participation in the CARE school powdered-milk distribution program. Key to the solution was the sale of the half-gallon tin cans in which the milk was supplied to peddlers, housewives, and small industry. As a matter of fact, when the first can auction took in $2,000, the secondary CARE ideas grew beyond water systems to other health needs.

In Denmark, last May, the rainwater supplies of the island of Saltholm—its only water—were cut off by edict when they were found to contain twice as

(Continued on page 46 P&R)



Here's Water Plant Control You Can Depend Upon!

This complete pneumatic system includes all the essential elements for the operation of water treatment plants. It is used for raw water flow control, flow measurement, chemical proportioning, level control and control of gravity filter operation.

Reliable mechanisms produce controlled air pressure for actuating meters, feeders and controllers and for measuring flow, head loss or water level.

The simplicity of this design offers you important plus values. Measurements are accurate and instantaneous. Operation is dependable. Maintenance is simple. *Write for Bulletin 1100.*

# C.-A.-P. SYSTEM®

## INSTRUMENTS

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**INFILCO Incorporated,** General Offices—Tucson, Arizona
Field offices throughout the United States and other countries.

911

(Continued from page 44 P&R)

much radioactivity as the international safe limit, the result of fallout from the nuclear tests of recent years. The immediate problem was solved by transporting drinking water to the 8-sq mi island by boat.

In Japan, a month later, it was sodium cyanide that served to create a drought, as a faulty pump at a chemical research institute in Tokyo poured approximately 45 lb of the chemical into the Zempukuji River. Not just no-drinking, but no-swimming and no-irrigating rules were enforced by special squads of police.

In Spain, meanwhile, one of our friends felt quite personally involved

---

**Se ruega encarecidamente a los Señores Clientes,** *CIERREN BIEN LOS GRIFOS Y DEJEN EL TAPON SIN COLOCAR,* **pues el Ayuntamiento corta el agua de 11 de la noche a 6'30 de la mañana.**

**On prie instamment messieurs les clients de bien vouloir fermer** *LES ROBINETS* **et de laisser le lavabo** *DÉBOUCHÉ,* **car la Municipalité coupe l'eau dés 11 heures du soir á 6'30 du matin.**

---

when, on his mirror at the Hotel La Perla in Pamplona, he found a sign (see cut) asking him to turn off his faucets and unplug his sink drain because the city shut off the water from 11 at night till 6:30 in the morning.

At Gibraltar, the waterlessness was more basic than that, stemming directly from rainlessness and impelling the city council to charter the Shell Oil Co. tanker, *Asprella,* to bring 4 mil gal of fresh water on her maiden voyage from Amsterdam to replenish the Rock's reservoirs.

St. Thomas in the Virgin Islands was in the same sort of boat-needingness, with no rain and no other sources of supply except the US Navy, which hauls water from Puerto Rico to augment the island's rain catchment system.

And even Mexico City had to scratch for more water, doing its scratching at Xochimilco, site of the famous floating gardens, where eight new wells are being drilled. As a matter of fact, Xochimilco, itself, has had to do some drilling of late to keep the gardens from going aground.

But it has been Britain that has been driest of all, from Scotland, whose burns are so birsled that approximately 25 per cent of the plants producing Scotch whiskey have had to be shut down, to England, whose hot spell has forced water consumption up approximately 50 per cent where water is available and brought about rationing where it isn't. For instance, at London, where, thanks to the Thames, it is available, consumption now totals 468 mgd, and at Bury, where it isn't, the Reverend Jeffreys Williamson of the Emmanuel Pentecost Church announced on Sep. 13 that, due to the drought, he was postponing all baptisms for 2 to 3 weeks.

If the nature of these problems would seem to indicate that it is, indeed, a dry world, perhaps that's what led Ippen to say it would happen: D day, that is—Dryday, the day when the world will reach the end of its available water supplies. But before you start hunting for a new job, be apprised that the professor also noted that before D day, "water will become a luxury as population increases." That will be *the* day!

(Continued on page 48 P&R)

# Pinched for pump space?

# Make the most of it with an Allis-Chalmers centrifugal pump

Let the world's broadest centrifugal pump line lead you out of your installation space squeeze. Here's versatility that blankets every suction or discharge requirement — with horizontal (see 1 to 4 illustrated) or vertical (see 5 and 6) mountings. Capacities run from a flow to a flood — to 250,000 gpm or more.

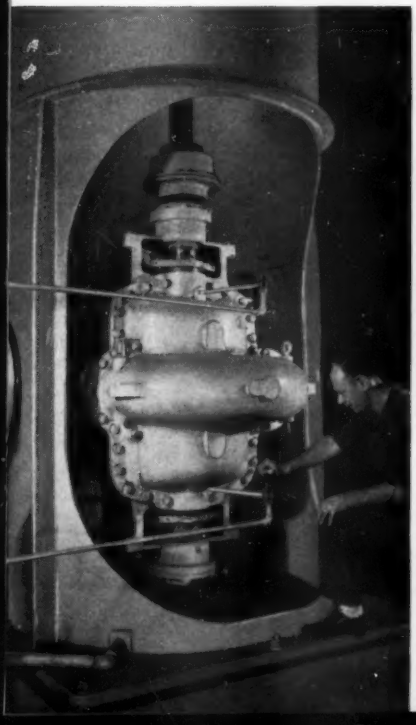
The size of the A-C pump line, the service and experience behind it, are without equal in industry. For data, contact your A-C representative or distributor. Or write to Allis-Chalmers, General Products Division, Milwaukee 1, Wis.

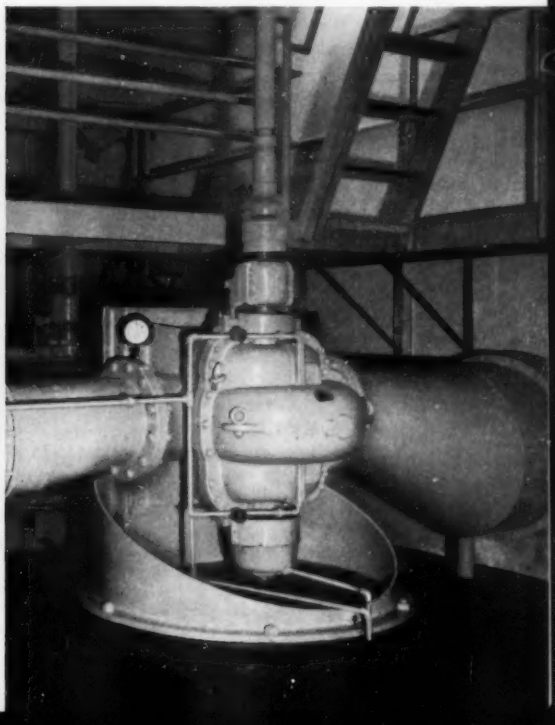
**ALLIS-CHALMERS**

A-1197-JAW

Vertical mounting with barrel supporting motor provides for discharge at either 90° to the suction (shown at lower left) or at 180° to the suction.

Mounted vertically, Allis-Chalmers pumps can be driven with motor on another floor — discharge at either 180° to the suction (shown at lower right) or at 90° to the suction.





(Continued from page 46 P&R)

**The order of the bath** in the Louisville, Ky., building code was recently declared unconstitutional by Judge Macauley L. Smith, who noted in his decision that "many people who have tubs or showers with hot and cold running water [as required by the code] are offensively unclean," whereas many who do not have such facilities "are fastidiously clean." Judge Smith's decision must, of course, be considered a blow to the water utility field, for, although it is use rather than availability of a tub that sells water, as someone other than Bill Mulholland said, "If you ain't got it, you won't use it!"

Meanwhile, in Bloomingdale, N.J., the law was getting ready to step into a hot bath argument, too, as resident Lawrence Frawley indicated his intention to continue flushing the hydrants in his vicinity every time he took a bath, so that he could get clean water. There, according to newspaper reports, the situation is complicated by the fact that water is supplied by neighboring Butler, N.J., from whom Frawley's complaints of muddy water have drawn only advice to "get it somewhere else." What we particularly liked about Frawley's spirit was his statement: "I pay $26 a year for my water and would be willing to pay $46 if need be, but why can't it be clean water?"

We see Frawley as one of Judge Smith's "fastidiously clean" guys, come well or high water rates. And recognizing him as one of those rare customers who knows he wants a "quality" water and appreciates that he will have to pay more for it, we like what we see!

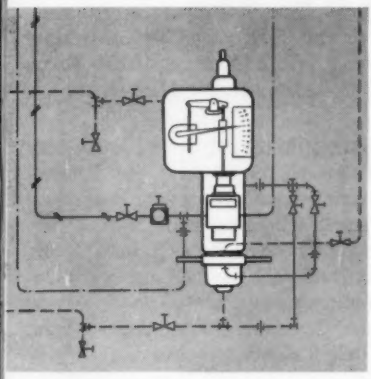
**For a pip of a pipe picture** our thanks go to William D. McCarney, Public Relations Dept., Keasbey & Mattison Co., Ambler, Pa. Seeing the pictorial possibilities in a pile of 12-in. asbestos-cement pipe in K&M's yards awaiting shipment, McCarney put his Speed Graphic to good use, as a glance at our front cover will prove.

**Strange bedfellows**, and not always compatible ones, have been water utilities and water-using industry. Where industry's tremendous requirements are self-supplied, there is, of course, competition for available resources. And where municipally owned utilities supply industry, too often they are faced with handling such business on an uneconomical basis as a means of, first, attracting and, then, keeping industry in town for its very real benefits to the community as a whole. There are, of course, many communities, such as Akron, Ohio, in which industry is, unquestionably, a "good" customer of the utility and neither eats crackers in bed. But utilities can be a little less than wild in their enthusiasm at the recent report by the accounting firm of Lybrand, Ross Bros. & Montgomery that a twelve-state survey indicated that water supply, among various other factors, is gaining in importance as an influence upon the location of US industry, whereas state and local taxes are diminishing in importance. Particularly will they restrain themselves in finding water supply listed as one of the "natural phenomena" that make industry pick one site above another. A good illustration of the uncertainty of the relationship, perhaps, is an advertisement of the Whiting Paper Co. of Stevens

(Continued on page 50 P&R)

# FLUIDICS

s a Pfaudler Permutit program providing a modern, imaginative approach — plus the specialized materials and equipment — for handling and processing and controlling more profitably the liquids and gases which are the lifeblood of our manufacturing economy.



FLUIDICS AT WORK

## New pneumatic transmission system more accurate, more dependable

The diagram shows a typical setup for the new Simplex system for transmitting rate of flow and loss of head to a receiver.

### Rate of Flow

The new Type PN transmitter combines the exceptional accuracy and range of a differential converter operated by a mercury float with the traditional dependability of pneumatic transmission.

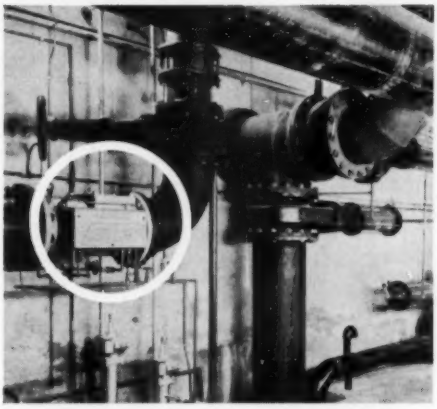
The transmitter consists of a differential converter which extracts the square root flow function from a primary and then positions a pneumatic motion transmitter. The transmitter produces a pneumatic 3 to 15 psig linear signal. A booster pitot diaphragm in the motion transmitter insures a low lag coefficient and fast transmission.

Besides getting a linear signal without using supplementary pneumatic relays, this new unit gives you point accuracy over wide ranges of flow with minimum differentials. The booster permits accurate transmission over long distances with minimum lag.

### Loss of Head

A Type TD transmitter gives accurate readings to within ±1%. It uses no stuffing boxes or relay valves, so both installation and maintenance are simple and economical.

Connected to Simplex Pneumatic Gauges, this new system will give long years of accurate, dependable, trouble-free service.



FLUIDICS AT WORK

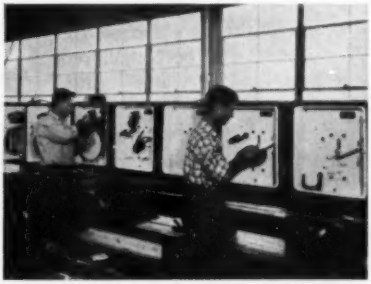
## Modulair Flow Controller installs as easily as a piece of pipe

So simple is this new pneumatic rate-of-flow controller, you can install it in about the time it takes to install a piece of pipe.

The differential producer and the modulator lie in a single housing. The actuator is entirely enclosed in a case which mounts directly on the housing.

**Result:** No complicated piping or drain system to install and maintain.

For a bulletin giving complete specs and performance data, write to our Simplex Division, Lancaster, Pennsylvania. Ask for Bulletin 951.



**Fast, dependable delivery insured by new plant**

This is the new $2,000,000 home of our Simplex Division . . . an ultra-modern plant designed from front to back to give you fast, dependable service on valves and meters. New manufacturing techniques, updated assembly lines and ample manufacturing capacity and a complete staff of skilled workers have all been planned around the single objective of getting your orders to you on time and built to your exact specifications.

# SIMPLEX

a division of PFAUDLER PERMUTIT INC.

Specialists in FLUIDICS . . . the science of fluid processes

(*Continued from page 48 P&R*)

Point, Wis., that appeared in the May issue of *Advertising Requirements*. On a page featuring a large "W," the ad read:

W is for Water. Well, not just *any* water. And not just any *well* water. It takes 99 gallons of water to process a single pound of paper—somewhat more than a drop in the old bucket, we'd say. So you'd find us the last to underestimate the importance of our pristine pure Whiting Springs in producing strikingly handsome letterhead paper (like Plover Bond). Miracle additives? We can't claim a one! The water of Whiting Springs is so perfectly distilled by nature that it needs no filtration, no harsh chemical treatments. Visibly better Plover Bond is *naturally* stronger, whiter, brighter.

Now, we have no complaint about this ad (nor, for that matter, about Plover Bond, which we use), but, eager as we are to have the powers of water praised, we rather doubt that the copy is anything for water utilities to cheer about. At the same time, the news from Standard Oil Co. (N.J.) that its engineers had found it possible to save up to $2,000,000 in building a completely air-cooled refinery, compared to a conventional water-cooled one, won't automatically be considered a complete loss to the water utility field.

From a different viewpoint, of course, industry—and particularly self-supplied industry—contributes a great deal to the advancement of the art, and its water supply operators and engineers are in the forefront of the field, meeting and helping to solve some of the most troublesome problems that water utilities face.

All of which may suggest: let's turn out the lights and go to sleep!

**Douglas Feben** has resigned as assistant superintendent of filtration at Detroit and is engaged in consulting practice. His address is 10134 Roxbury Ave., Detroit 24, Mich.

**Philadelphia held open house** last month for visitors to its new Torresdale water treatment plant, billed as "the world's biggest pushbutton water works." The $25,000,000 installation will normally treat 282 mgd, with a maximum capacity of 423 mgd, and is expected to meet the needs of more than half the city's population for the next quarter century. An eye-appealing collection of light brick buildings, huge expanses of glass, fluorescent-lighted interiors, great outdoor basins, and laboratories, the plant provides chemical treatment, sedimentation, and rapid sand filtration facilities in an area of only 10 acres. Automatic programing and semiautomatic controls will make it possible to operate the plant with 75 employees. The opening of Torresdale marks the completion of one of the key steps in the modernization of Philadelphia's water supply system.

**Paul A. Harlamert,** Cleveland, Ohio, district manager of Johns-Manville's Pipe Div., has been made a partner in the consulting firm of Jones, Henry & Williams, Toledo, Ohio.

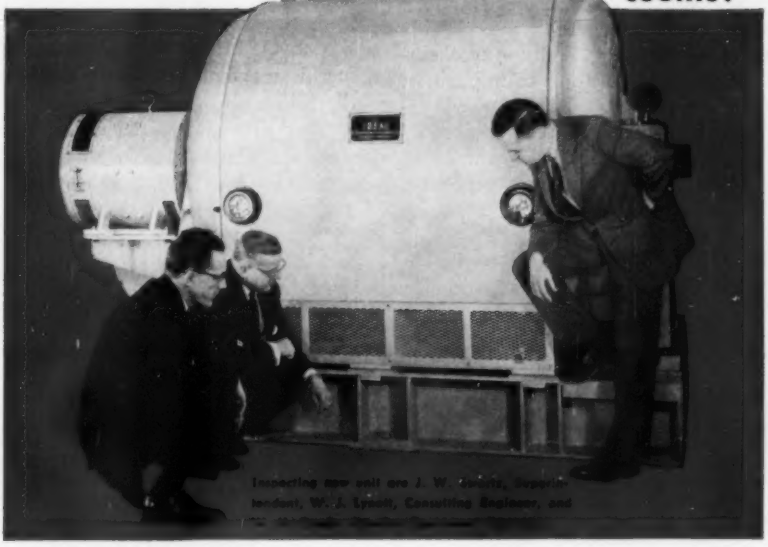
**"How to Get Rich"** was the caption on a story from Crescent City, Calif., last month, telling the story of contractor Tom Hull, who was paid $1,800 to build a water tank for that city 40 years ago and $2,000 this year to tear the same tank down. "But Not Quick," we might add.

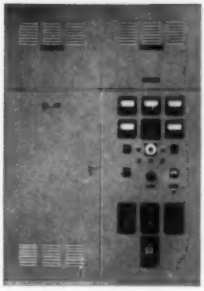
(*Continued on page 52 P&R*)

. . . because

# PERFORMANCE

counts!





The Hackensack Water Company, Hackensack, New Jersey, like many users of IDEAL equipment, again selects IDEAL on the basis of proven performance.

A new 2000 HP, 720 RPM synchronous motor, with control shown left, duplicates an IDEAL unit that has been in operation since 1954. There are good reasons why progressive commercial and municipal water suppliers—and others who require the utmost in performance and dependability—repeatedly choose IDEAL.

For complete details write for bulletin 501

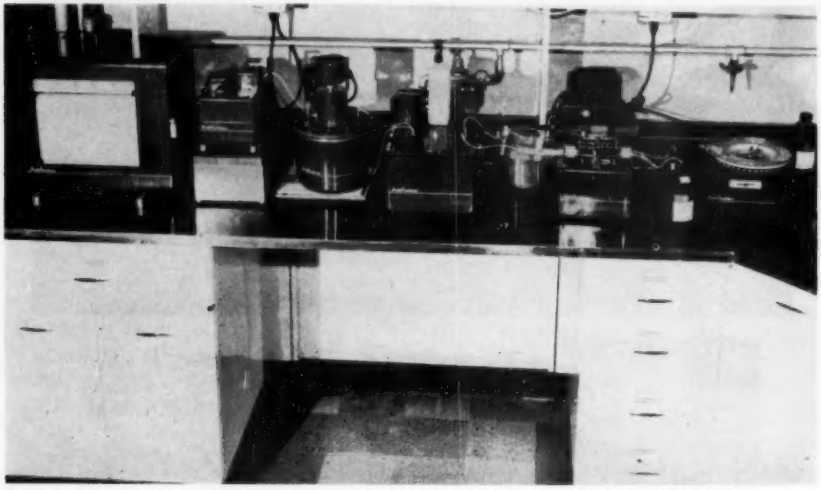
The IDEAL ELECTRIC & MANUFACTURING CO.
320 East First St. Mansfield, Ohio

SINCE 1903, AMERICA'S FINEST MOTORS, GENERATORS, MOTOR-GENERATOR SETS, SWITCHGEAR AND CONTROLS

(Continued from page 50 P&R)

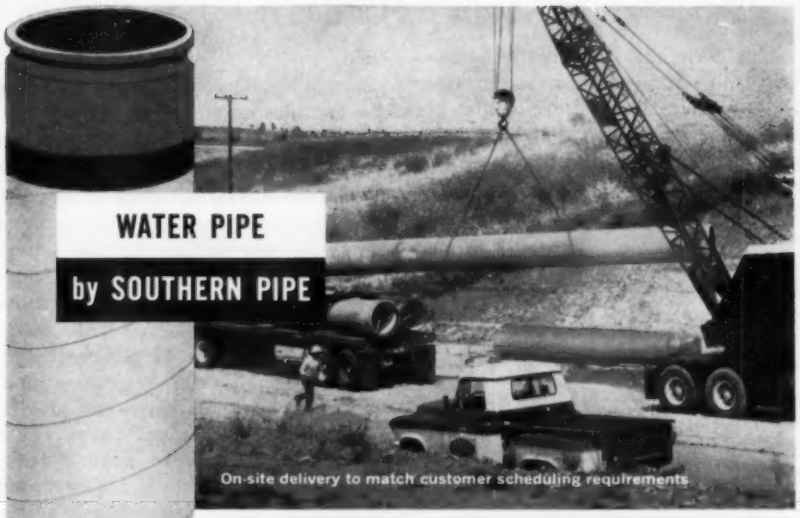
**The Autoanalyzer,** recently announced, disappoints us. Not at all the do-it-yourself psychiatrist's couch we visualized, it turns out to be only a photoelectric colorimeter equipped with automatic devices which provide continuous sampling, addition of chemical reagents, separation of impurities, mixing, measuring of color, and recording of results. Properly calibrated for each analytical method, it can carry out as many as 60 analyses per hour, but is unable to detect the simplest of Freudian slips. Put to work by Water Service Labs., Inc., New York firm of research and consulting chemical engineers, the Autoanalyzer (see cut) will be doing the bulk of some 5,000 analyses per week of samples taken from air-conditioning installations, domestic water systems, and boilers in an investigation of corrosion. Among the characteristics it will be used to measure are silica, phosphates, iron, copper, sulfates, and chromates—many of them in parts per billion—but it can't even guess at frustrations. Autoanalysis, our foot, this is mere mechanical wizardry!

**Lynn O. Minor,** vice-president and general manager of the Kankakee (Ill.) Water Co., will retire in January after 47 years in the water utility business. He has been manager at Kankakee since 1939.



**Powdered water,** a form of our product made possible by a new process of microscopic encapsulation developed by the National Cash Register Co., evokes almost as interesting possibilities as the entirely wistful thought of "instant water." The big drawback with powdered water is that, instead of leaving "nothing" to transport or store or deliver as would dehydration, encapsulation will increase the bulk of the product by approximately 43 per cent over its original form.

(Continued on page 54 P&R)

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Southern Pipe customers enjoy these ONE LOCATION benefits for welding, fabrication, coating, and lining of water pipe:

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- integrated scheduled production
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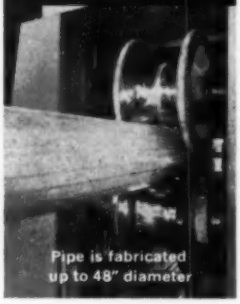
Write now for literature describing the most completely integrated installation of protective coating, lining, and pipe producing equipment in the west.

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## Southern Pipe

DIV. OF U.S. INDUSTRIES, INC.
P.O. Box C · Azusa, California
CUmberland 3-7111 · EDgewood 7-1221

(Continued from page 52 P&R)

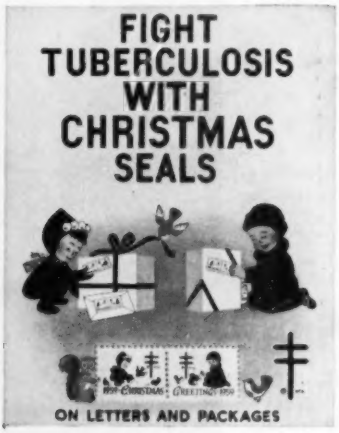
The technique of encapsulation—that is, of turning liquids into powders—involves, first, breaking the liquids up into droplets of microscopic size and, then, coating each droplet with a thin layer of gelatin. The result is a capsule perhaps a millionth of an inch in size. In bulk these capsules form a fine powder which is dry to the touch, although 70 per cent of its bulk is liquid. When wanted, the stored liquid is released either by crushing or by dissolving the capsule.

First commercial application of the process is the NCR "no-carbon-required" paper that makes copies without carbon paper, now being used on many bank deposit slips and other forms. Secret of this process is a light clay coating on the front of the paper and an encapsulated oil on the back. Pressure of a pencil or typewriter on the paper crushes the capsule, releasing the oil, which reacts with the clay to form a bright blue dye. But NCR has many, many other ideas for applying the process—in the memory units of electronic computers, in the drug field, in the development of "dry" photography, possibly even in using the capsules as tiny electric cells.

Our thoughts, though, turn to water—and not to such puny possibilities as that of encapsulating distilled water to protect its purity, but to the idea of providing dry storage for the waters of the Southwest and thereby completely eliminating the pressing problem of evaporation. Even if the warehouses had to have 43 per cent more capacity than do the reservoirs now, the problem of siltation would also be solved, and present reservoirs could be devoted entirely to flood control. Reliquefication could be accomplished as required by the use of large presses of the type now employed in the paper industry.

In eliminating the threat of contamination and corrosion, powdered water could also provide useful emergency storage possibilities wherever form rather than space was the determining factor. As a matter of fact, we could manage to find room for a few pounds in our golf bag for those frequent courses that locate their only water fountain at the second tee. But beyond the necessities of simple storage, think of the possibilities for dry-wash cloths, on ski slopes, in pullman washbasins, or in frozen form to cool really dry martinis.

We look forward to the day when "take a powder" will mean "flow" instead of "blow."

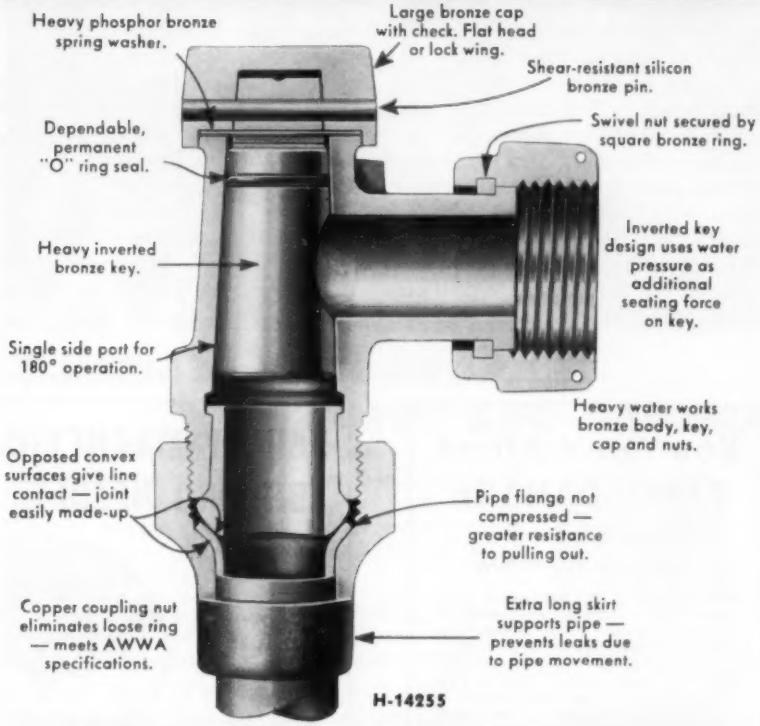



**Charles Kuhn** has been named vice-president and sales manager of Dresser Mfg. Div., Bradford, Pa., maker of pipe joining and repair products. Kuhn has served the division as sales manager since 1958.

(Continued on page 56 P&R)

# *use* MUELLER®
# *angle meter stops*

**. . . the angle meter stop with "O" ring seal!**


Heavy phosphor bronze spring washer.
Large bronze cap with check. Flat head or lock wing.
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Heavy water works bronze body, key, cap and nuts.
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Extra long skirt supports pipe — prevents leaks due to pipe movement.
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MUELLER CO.
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Factories at: Decatur, Chattanooga, Los Angeles;
In Canada: Mueller, Limited, Sarnia, Ontario

(Continued from page 54 P&R)

**AWWA'ers in the news** during the past month included:

● Armand D'Angelo, New York City commissioner of water supply, gas, and electricity, who was presented with the Eloy Alfaro International Foundation's Grand Cross and Diploma in recognition of the commissioner's "extraordinary, distinguished, public, patriotic, philanthropic, religious, and humanitarian services to mankind and his efforts toward the establishment of international peace." The foundation was set up in honor of Eloy Alfaro, onetime president of Ecuador. The presentation was made by Mayor Robert F. Wagner.

● Robert W. Gregory, superintendent of the Cone Mills Corp. water system at Greensboro, N.C., who resigned his position to campaign for election to the US Senate in 1960 on a platform stressing health research. He had completed 30 years of service with the textile firm and has been a member of AWWA since April 1939.

● W. Fred Welsch, senior hydraulic engineer, Nassau County (N.Y.) Dept. of Public Works, who received the top award of the American Public Works Assn. for public service. Known as the Nichols Award, it carries an honorarium of $500. Welsch was cited for "his pioneering and sustained leadership in the development and administration of a program of artificial recharge . . . with storm water . . . and for his technological contribution to the science of ground water conservation." He has been with Nassau County since 1935.

(Continued on page 60 P&R)

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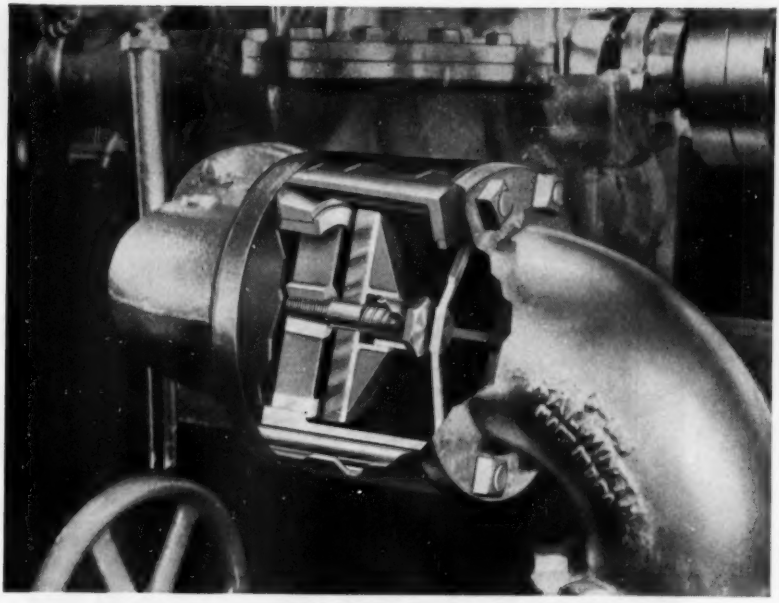

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When CPV silent, non-slam check valves are installed on the discharge of centrifugal pumps, the whole system is protected against waste and harmful surges. The need for expensive air cushions and other anti-hammer devices is eliminated.

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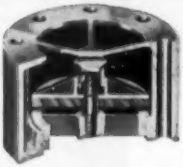
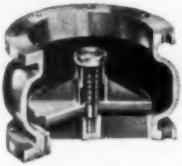
Users report CPV valves easy to install and require no maintenance. Unique design includes bearing guides on both sides of disc and a full flow area in excess of pipe area. The valve operates in any position.

For complete specifications and prices write Combination Pump Valve Company, 853 Preston Street, Philadelphia 4, Pa.



STYLE "G"—2 to 10"



STYLE "GB"—6" and up

CPV SILENT NON-SLAM CHECK VALVES

FOUNTAIN OF YOUTH, 1880... The well of the Little Red Schoolhouse was a popular, if not always healthful, gathering place for children. The old tin dipper in its lip-to-lip travels carried more than its share of disease.

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FOR WATER, SEWERAGE AND

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The nation's health depends largely on water. And most of this water is distributed through cast iron pipe.

U. S. Pipe, therefore, exerts every effort to make its product dependable, long-lived and trouble free. From mining of ore... through blast furnace... to final shipping, every length of U. S. Cast Iron Pipe is checked and rechecked for quality.

This end-to-end supervision is another reason U. S. Pipe measures up to the promises made for it... and to the responsibilities placed on it in service.

**QUALITY BEGINS HERE** . . . at one of U. S. Pipe's mines near Birmingham where ore is mined.

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**2 Park Avenue** **New York 16, N.Y.**


*(Continued from page 56 P&R)*

**Harry N. Dietz** has been appointed a vice-president of Orangeburg Mfg. Co., a division of Flintkote Co. He will make his headquarters in New York and will continue in charge of conduit sales. Mr. Deitz has been with Orangeburg since 1939.

**Engineering society news** last month included the announcement that Frank A. Marston, partner in the consulting firm of Metcalf & Eddy, Boston, has been installed as the new ASCE president. ASME's newly elected president, Walter L. Cisler, president of Detroit Edison Co., takes office at the end of November. October also saw the start of work on the United Engineering Center, with Herbert Hoover doing the honors at the ground-breaking ceremony. The multimillion-dollar eighteen-story structure, located across the street from the United Nations in New York, is scheduled for completion in 1961.

**Thomas E. Stanton,** a 22-year veteran of the Cleveland, Ohio, Water Dept., has been appointed city commissioner of water and heat. He succeeds Frank J. Schwemler, who resigned several months ago.

**The Post Office** has asked us to publish this reminder:

*To insure expeditious handling and prompt delivery of all mail during the Christmas holiday season,* mail early! *And follow these ABC's of good mailing habits:*

"A" postal delivery zone number helps speed your mail.

"B" certain to include your return address on all mail.

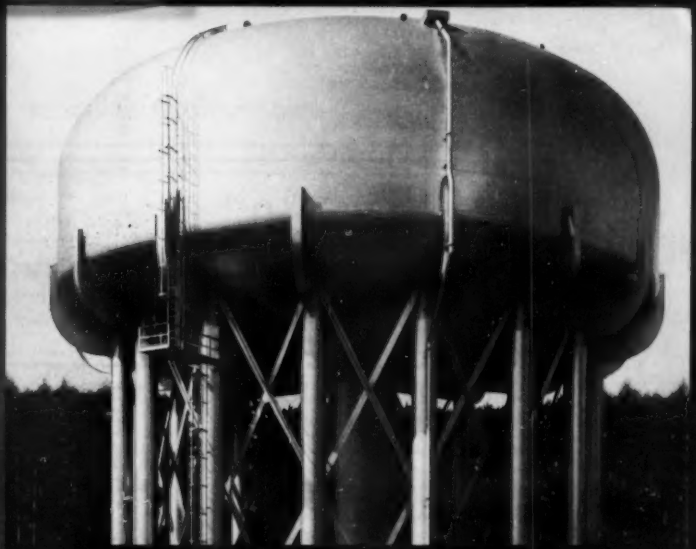
"C" that the delivery address is correct and complete.

*And mail early in the day—it's the better way.*

*(Continued on page 100 P&R)*

PDM
ELEVATED STEEL TANKS

# ELEVATED STEEL TANKS



Radial cone tank, Seattle, Wash. Capacity 2,000,000 gallons.

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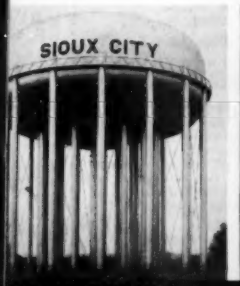


Toro-segmental tank, Sioux City, Ia. Capacity 2,000,000 gallons.

Radial cone tank, Independence, Kansas. Capacity 750,000 gallons.

Double-ellipsoidal tank, Melbourne, Fla. Capacity 300,000 gallons.

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# Condensation

**Key:** In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, **39**:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

## FILTRATION

**Enclosed Removal of Iron by Rapid Filtration.** J. Holluta & M. Eberhardt. Vom Wasser (Ger.), **24**:79 ('57). Authors describe an investigation of processes in removal of iron from water by filtration, made with objects of developing a formula of measurement and testing depth of penetration of iron in filter bed. Small-scale exptl. plant in which expts. were carried out is described and illustrated. Under normal conditions (pH 7–7.5, saturation with air, temp. 13°–16°C), removal of iron in sand filter followed an exponential law. Chem. oxidation of iron as slowest part of process detd. rate of removal of iron, which was also dependent on iron content of water and the pH value and was accelerated by contact catalysis with separated iron hydroxide. Changes in form of iron within filter and avoidance of breakthrough of iron are discussed. An equation is developed which takes into act. depth of filter, rate of filtration, size of filter sand, and content of iron in water.—*WPA*

**Filtration According to the Immedium Principle.** W. J. Smit. Water, Den Haag (Neth.), **41**:252 ('57). Immedium filters have been introduced at pumping station of water works at Oud-Beijerland (Neth.). Principles of operation and design of these filters are discussed; Immedium filters are normally operated as closed filters and problem of adapting them for use as open filters is considered in detail. Diagrams are given of old and new filtration systems. A new method of cleaning filter is included, based on passing compressed air under filter bed; better results are obtained by passing air in intermittent blasts than by same quant. of air in one continuous blast. Installation consists of 4 open filters, each having a filtering surface of 10 sq m; surface area of drainage system is 12% of tot. area of filter. Results obtained using these filters are tabulated showing daily capacity of filters, and percentage removal of impurities from water.—*WPA*

**Emergency Diatomaceous-Earth Filtration, Wakefield, Mass.** G. J. Coogan. Sanitalk, **6**:2:4 ('58). To meet needs of Wakefield, Mass., during drought of 1957, water was drawn from L. Quannapowitt, which is normally used for recreational purposes. Water was chlorinated and filtered through diatomaceous-earth filters. Design and operation of these filters are described. Rapid clogging of filters occurred, owing to type of water, and backwashing was necessary about every 30 min; however, output of filtered water was about 650,000 gpd. Diatomaceous-earth filters are considered satisfactory for emergency treatment of moderate quants. of water, but cost of such treatment is rather high. Chlorination facilities should always be provided, owing to possibility of failure of alumina tubes. Bacteriol. and chem. tests at Wakefield showed that all coliform organisms and all algae were removed from water; color was reduced from 90 to 15 ppm, turbidity from 20 to 3 ppm, and tot. content of iron and manganese from 0.75–1.0 ppm to 0.14 ppm.—*WPA*

**Diatomaceous-Earth Filters for Potable Water.** Bul. Mens. Centre Belge et Document. Eaux (Belg.), **78–79**:301 ('57). Reasons for limited use of diatomaceous filters in United States are outlined, and results of a survey of the 29 such installations which existed in '56 are discussed. Turbidity was removed satisfactorily; color was only partially removed; at one plant iron content was successfully reduced from 0.56–1.85 ppm to less than 0.01 ppm. Costs of operation are considered and means of improving tech. and economic efficiency of plants are suggested. —*WPA*

(*Continued on page 72 P&R*)

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LIFE

(Continued from page 70 P&R)

**Rapid Sand Filters Replace 50-year-old Equipment at Philadelphia's Torresdale Water Plant.** S. S. BAXTER & M. G. MANSFIELD. Civ. Eng., 27:311 ('57). At Torresdale water works of Philadelphia, Pa., water from Delaware R. is treated by coagulation and prelim. sedimentation, prelim. chlorination, roughing filtration thru mechanical filters, final filtration thru slow sand filters, and postchlorination. During peak periods plant is operating at full capacity, and will be unable to meet addnl. demand placed on it when pumping station on the Schuylkill R. and Roxborough filter plant are closed down. Addns. and extensions are therefore being made to increase avg. capacity of plant to 282 mgd with a max. capacity of 423 mgd. Water will be settled in existing prelim. sedimentation units, and passed to prelim. treatment plant for chlorination, coagulation with lime and alum, and sedimentation. Settled water will pass thru new rapid sand filters, and effluent will be treated with lime for adjustment of pH value, phosphate for control of corrosion, chlorine, and fluoride. Water will also be treated when necessary with carbon and chlorine dioxide for control of tastes and odors. Existing slow sand filters will be converted into a filtered-water reservoir, thus increasing storage capacity of plant by about 150 mil gal.—*WPA*

**Action of Certain Surfactants Upon the Filration of Aqueous Suspensions.** F. EDELINE & R. VAN ACHTER. Bul. Centre Belge et Document. Eaux (Belg.), 3:41:241 ('58). Addn. of 10 to 500 ppm of anionic and nonionic surfactants to a suspension of C caused filter cake to have a lower $H_2O$ content; from 21.6–22.6% it decreased to 13.4–19.2%. At same time, duration of filtration of a std. soln. increased markedly. This is attributed to a denser cake resulting from layering of flat particles. A filtration equation based upon Poiseuille's law was not followed due to size segregation and settling during filtration.—*CA*

**New Method for Studying Flow in Porous Filter Media.** G. MATTA. C.R. Acad. Sci. (Paris), 244:2770 ('57). To study flow thru porous filter media, porous medium is represented by a network of capillary tubes interconnected to one another, and potentials at different points are measured by means of manometers connected to intersections of capillaries.—*WPA*

## CORROSION

**The Aggressiveness of Water in Relation to Cement and Concrete (Fr.).** F. PAIX. L'Eau, 44:217 ('57). Various types of cement are described physically and chemically. Detailed descriptions are given concerning effects of different waters on cement in reference to clean water, sulfate water, ocean water, action of carbonic gas, and waters containing gases. Formulas and graphs are given, indicating some of effects, especially in relation to carbonic gas. Mixing water is discussed in relation to production of concrete. Soils are considered from point of view of possible damage to concrete through different types of corrosion. Finally, phys. characteristics of concrete needed to resist corrosive action of water and soil are described.—*PHEA*

**Connecting Copper Household Pipes to Cast-Iron or Steel Main Water Pipes.** B. ZANDVELD. Water (Neth.), 41:37 ('57).

(Continued on page 74 P&R)

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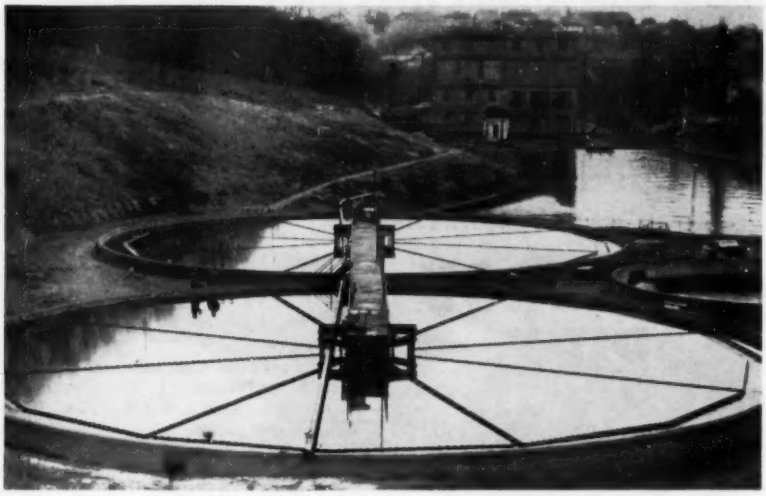

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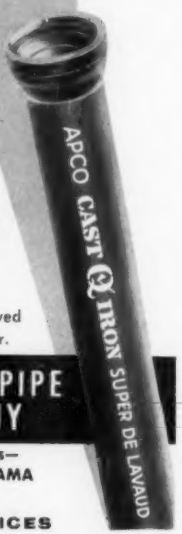


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(*Continued from page 72 P&R*)

Connecting copper household pipes to cast-iron or steel mains is cause of corrosion of main due to electrochem. phenomena. Intensity of corrosion depends on resistance of soil (which acts as electrolyte), length of household pipes, no. of connections per unit of length of main, and state of isolation of main. Corrosion can be prevented by an isolating intermediate, but this prevents household pipe from serving earth for elec. machines. Same considerations apply to brass valves losing Zn when used for connecting asbestos-cement pipes to copper pipes. Use of bronze intermediates can minimize corrosion.—*CA*

**The Influence of Corrosion on the Quality of Drinking Water.** L. ROTT, ET AL. Orvosi Szemle (Rum.), **6**:333 ('58). Reasons were sought for turbidity, yellowish color, and unpleasant taste of drinking water supplied to town by a 1955 treatment installation. Water originates from a river, is purified by coagulation with Al sulfate, and brought into town by a 14 km steel pipeline. A neg. stability index, high concn. of $CO_2$, and increased iron concn. indicate corrosion processes in pipeline, due to fact that in soft river water purified with $Al_2(SO_4)_3$, $CO_2$ is liberated.—*CA*

**Variable Interaction: A Statistical Solution.** H. C. BOWEN; C. GROOT; & J. L. JAECH. Corrosion, **15**:83 ('59). Tests were run to det. whether occasional use of tap water in place of deionized water in cooling system of a nuclear reactor with Al-clad fuel elements would cause excessive corrosion. While tap water corroded samples 3 times as fast as deinonized water, corrosion in one month was only 65% of that in 3 months. It was concluded that single change to tap water would have little effect, and that tap water would be used for cooling in emergencies.—*CA*

**Protection Against Scale and Corrosion by the Silica Phosphate Inoculation Process.** NADELBACH. Literaturber. Wasser, Abwasser, Luft & Boden, **6**:37 ('57). Hard water may cause formation of scale which can be removed by acid treatment or mech. cleaning. These methods, however, do not remove nuisance of iron sludge formed by corrosion by soft or aggressive water with acid elements.

(*Continued on page 76 P & R*)

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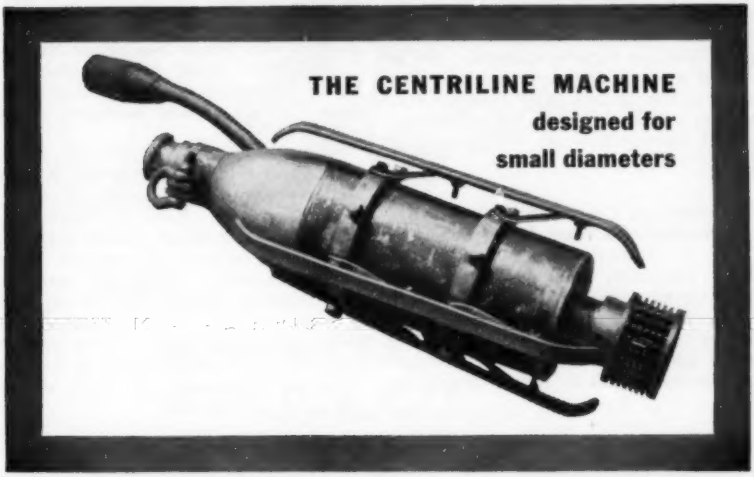


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(Continued from page 74 P&R)

Damaging constituents can be removed from water by pptn. or ion exchange. Author describes a process in which hardness formers are kept in soln. by addn. of polymeric phosphate, preferably in amt. of 2 mg/l. Dissolved iron in small amts. (up to 0.3 mg/l) is stabilized. Combination with silicic acid makes method independent of small amts. of hardness forming materials; this is important for soft aggressive waters. For silica-phosphate process it is essential that addns. are accurate, regular, and continuous, but brief interruptions are not harmful.—*WPA*

**Observations on Corrosion in the Distribution System of a Plant Using Sea Water.** N. A. MALISCHEVSKI. Literaturber. Wasser, Abwasser, Luft & Boden, **6**:35 ('57). Author describes expts. on effect of water from Caspian and Black Seas on steel, cast iron, brass, and bronze. An anal. is given of salts present in 2 waters. Attack on metals was found to depend largely on salt content. Amt. of metal lost per hr was almost doubled at a salt content of 0.5 ppm. Higher contents of salt increased loss but not to a great extent. Temp. exerted a considerable influence, corrosion losses being considerably greater at 50° than at 20°C. This is ascribed to increase in speed of electrochemical reactions. Corrosion was greater with Black Sea water than with Caspian Sea water, probably because of higher content of magnesium chloride. Increase in rate of flow increased corrosion. —*WPA*

**A Method of Determining the Biological Action of Synthetic Materials.** A. MUELLER & W. SCHWARTZ. Suppl. to Staedtehygiene, **8**:11:4 ('57). Authors describe method used in expts. on resistance of synthetic materials to bact. corrosion. Tests were made using microorganisms which might be expected to have a corrosive action on material being tested which formed only source of carbon. Control series were run without any source of carbon, with paraffin as source of carbon,

(Continued on page 78 P&R)

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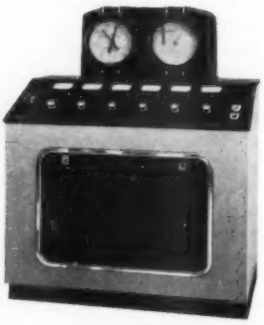

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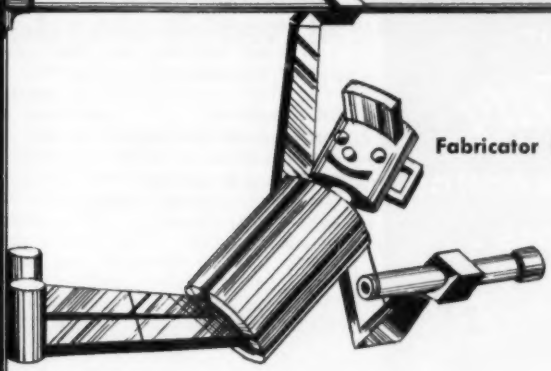

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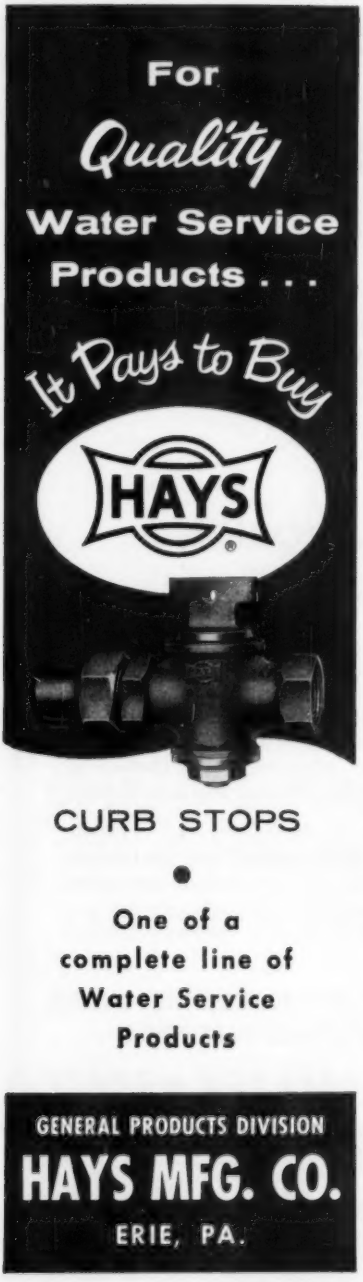


(*Continued from page 76 P&R*)

and without bact. inoculation. During last 4 yr many materials have been examined, and authors give results of tests with 2 types of synthetic material used for water pipes. Test organisms were *Pseudomonas aeruginosa*, a mixture of fungus and bact. from a damaged hemp and bitumen packing, and a mixture of bact. strains from process water of a factory making synthetic materials. In general results show that, after a preliminary rise in bact. nos., there was a decrease, which, with a sufficiently long period of expts., gave nos. corresponding to those of carbon-free control. After 5 mo, no signs of bact. corrosion were found.—*WPA*

**Corrosion by Drinking Water.** T. SAMUEL. Bul. Mens. Centre Belge et Document. Eaux, **80–81**:325 ('57). Author describes studies carried out on aggressive action of soft water. Steel indicator tubes were placed in 2 distribution systems, aggressive character of waters being widely different in each case. Tubes were examined after 2½–5 mo and photographs of rust are given. In 1 tube metal showed slight general corrosion and in other, local corrosion by pitting. Depth of pitting was measured and results are given in histograms. Corrosivity of several types of water was measured using a corrosimeter which determines quantity of iron passing into soln. each day and results are given in graphs.—*WPA*

**Tests of Corrosion Inhibitors Made on Treated Water From the Water System of the Eupen Dam.** J. BALTHAZAR. Bul. Mens. Centre Belge et Document. Eaux, **61**:5 ('56). Author describes 2 methods of testing effectiveness of phosphate compounds as corrosion inhibitors. In a static method a corrosimeter was placed in a flask contg. water to be tested. Water was changed after 24 hr and concn. of dissolved iron determined. A summary of results is given. In a dynamic method, water contg. hexametaphosphate was passed over small polished steel plates. It was found that after 3 mo plates immersed in treated water contg. no phosphate were heavily corroded, but those in water contg. phosphate showed only a few pits.—*WPA*

**Corrosion in Scotch Marine Boilers. I. Model Boiler Tests on Corrosion of Mild Steel Tubes in Highly Saline Waters.** F.

(*Continued on page 80 P&R*)

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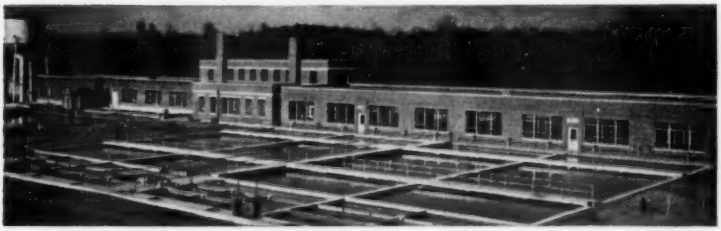

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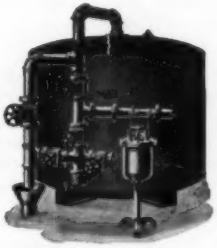

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(Continued from page 78 P&R)

WORMWELL; G. BUTLER; & J. G. BEYNON. Using model boilers, qual. and semiquant. expts. were carried out on corrosion of internally heated boiler tubes in conditions simulating those in Scotch boilers. It was found that depth of pitting on mild steel boiler tubes in distilled water with additions of sea water increased with density of soln. and with increase in oxygen concn. of feedwater from 4 to 15 ml/l. Boiler waters with a density of 2½ oz/gal and greater become acid under operating conditions. When water was kept alkaline by addn. of sodium carbonate to feedwater, depth of pitting was reduced markedly, and increase in concn. of oxygen in feed water did not increase depth of pitting. **II. Model Boiler Tests on Influence of Copper Content of Steel on Corrosion of Tubes in Artificial Sea Water.** G. BUTLER & H. C. ISON. Expts. were carried out in model boilers to det. effect of copper concn. of steel on resistance to corrosion of mild steel boiler tubes in artificial sea water. Results, using steel contg. from <0.01% to 0.20% copper, showed value of copper in reducing severity of pitting of tubes in acid conditions that develop in a boiler when water is not treated. When boiler water was kept alkaline, pitting was slight and was not reduced by presence of copper in steel. Copper appears to stabilize original mill scale, pitting largely localized at breaks in this scale.—*WPA*

**Corrosion Control in Water Works Systems.** W. E. PFEIFFER. Southwest Water Works J., **38**:9:36 ('56). In a paper presented at the 25th Annual Arkansas Water and Sewage Conference ('56), author discussed control of corrosion in water systems. A procedure which has gained wide acceptance for prevention of corrosion involves control of deposition of calcium carbonate scale on metal by addn. of lime. Author describes mechanism of corrosion and deals with use of inhibitors as a means of control. Advantages and disadvantages of various inhibitors used are given.—*WPA*

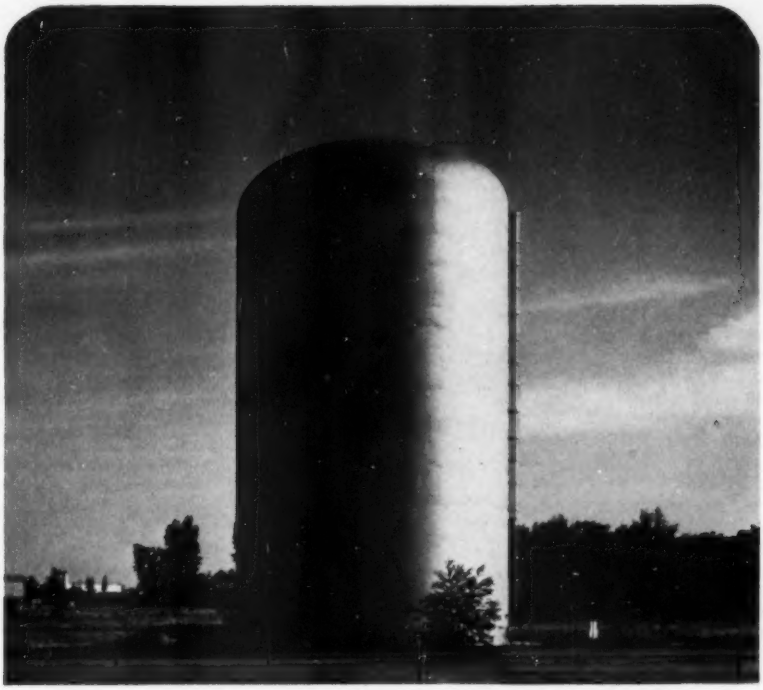
**Corrosion of Metals in Buildings.** S. BAKER & E. CARR. Chem. Ind., p. 1332 ('57). In an article on corrosion of metals in buildings, authors deal with behavior of copper and its advantages over other metals which have led to its widespread use in building construction. List of its main uses is given. Among the topics discussed is use of copper pipes for water supplies, and effects of hard, soft, and aggressive water on copper. Occurrence of pitting, and corrosion in aggressive water resulting in "green staining," prior to formation of protective coating of copper oxide and carbonate, are discussed in detail. If green staining persists, authors recommend water treatment as most satisfactory soln. to problem, as use of lead pipes may cause lead poisoning, and iron pipes give rise to "brown staining," and rust too rapidly to be economical. Occasional corrosion of copper boilers and cylinders by "dezincification" of brazing metal or by galvanic corrosion, and methods of prevention, are described. Authors recommend extensive use of copper for pipes, as it is nontoxic to humans in concns. in which it occurs in water when used, and enumerates MPC's.—*WPA*

## FOREIGN WATER SUPPLIES

**Sanitation of the Town of Tafi Viejo, Province of Tucuman (Argen.).** C. A. MAYORAL. Rev. Obras Sanit. Nación (B. Aires), **39**:91 ('57). Development of water supplies and sewerage system for town of Tafi Viejo is described. Water is drawn from wells in valley of Taficillo and Nueva Esperanza and in region of town, from springs in the San Javier mountains, and, in an emergency, by means of an aqueduct from river Vipos. Distribution of water from 2 reservoirs, having capacities of 1,500 and 1,000 cu m, respectively, is also described. Filtration galleries normally produce a clear water which only requires treatment with sodium hypochlorite. Avg. demand of town in 1956 was 5,000 cu m/day. A map is included showing layout of water supply system for towns of Tucuman and Tafi Viejo. —*WPA*

**The Water Supply of Vienna (Austria).** W. SCHMIDT. Wasserwirtsch. Wassertech. (Ger.), **7**: 114 ('57). Author describes, with maps, positions and yields of various springs which supply water to Vienna. Some of intake plants are combined with power works; power is used to pump water and to supplement town's electricity supply. Storage and distribution systems are described. —*WPA*

(Continued on page 82 P&R)



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(*Continued from page 80 P&R*)

**The Distribution of Water in Belgium.** Tech. Eau, **11**:126:43 ('57). Water resources, and consumption and distribution of water in Belgium are discussed, and problems connected with increasing use of surface waters and development of distribution systems are considered. Data relating to consumption of water by various industries in '56 are tabulated; nonindustrial uses amt. to only about 15% of tot. About 75% of pop. are served by distribution systems.—*WPA*

**Basic Step Toward Full Utilization of River Nile (Egypt).** M. A. SELIM. Civ. Eng., **28**:55 (Aug. '58). Countries along 4,160 mi of Nile R. are wholly or partially dependent upon this great river. A step towards complete utilization of Nile, construction of new High Aswan Dam (called Sadd-el-aali) will be completed within 10 yr at an estd. cost of $344,000,000. New dam will be located between rock banks 3.7 mi south of existing Aswan Dam. After completion High Aswan Dam will have a gross reservoir capacity of 105,400,000 acre-ft. This capacity will allow for over-year storage, a process in which water is stored in good years to meet requirements in bad years, and is sufficient to permit future agricultural expansion in both Egypt and Sudan. Present Aswan Dam and other existing control dams along Nile at best can only store sufficient water to supplement normal low summer flow and just meet present requirements. New dam will be rock-filled with a clay core, 16,400-ft long and 360 ft above river bed. Construction will make necessary diversion of entire flow of Nile. —*PHEA*

**The French Departmental Effort in the Sphere of Drinking Water Supplies.** Tech. Eau, **10**:115:45 ('56). Work of supplying drinking water to communities in departments of Seine-et-Oise, Eure-et-Loire, Morbihan, and Savoie, is summarized.—*WPA*

**International Building Exhibition, Berlin (Ger.), 1957—Water Supply in the Newly Reconstructed Hansa Quarter.** R. HAASE. Gas- u. Wasserfach., **98**:811 ('57). Author describes layout of distribution system in rebuilt Hansa quarter in center of Berlin and arrangements made to increase pressure in buildings 8–17 storys high.—*WPA*

**Water Supply Between Harz and the Heath—A Glance Into History (Ger.).** H. SCHREWE. Vom Wasser, **24**:9 ('57). Author gives a historical survey of water conditions in district between Harz Mountains and Luneburge Heath, dealing with district in 3 sections, mountain district as source of water, plains below mountains which are supplied with water from mountains, and Luneburge Heath, where there is deficiency of water. Development of use and control of available water is traced from 1st Century AD and present conditions of industrial development, water supply, and soil improvement are described.—*WPA*

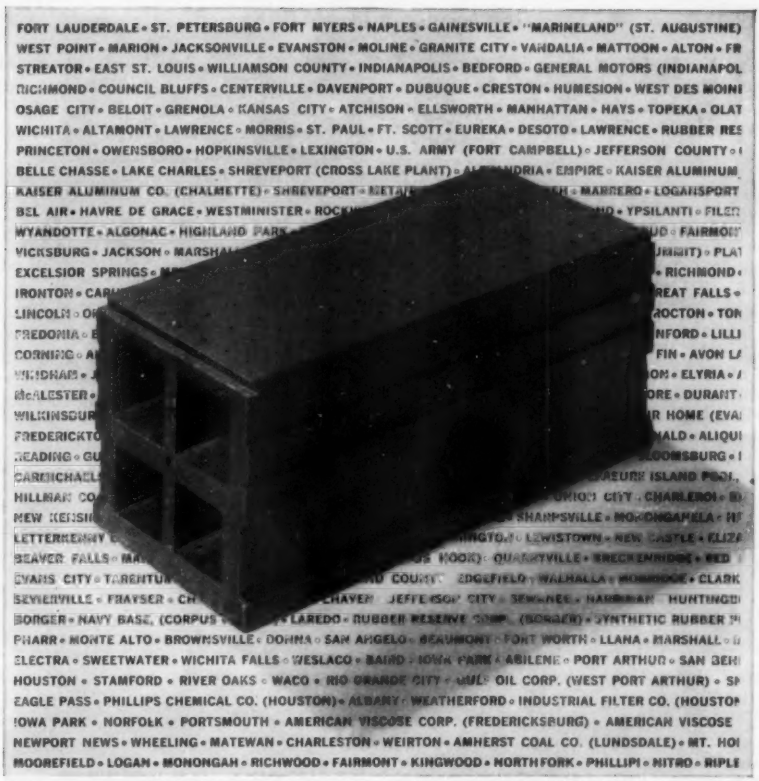
**Water Supply Problems in a New Town Area (Gr. Br.).** L. J. SLOCOMBE. J. British Wtr. Wks. Assn., **39**:674 ('57). Author outlines legal problems encountered in connection with a water supply for new town area of Welwyn Garden City, Herts. Water supply for district is at present obtained from council's water works consisting of six deep wells. Max. permitted extraction is 2.5 mgd and therefore a scheme to provide another 2 mgd has been suggested. Scheme includes construction of new wells and water works and an additional 2 mil gal reservoir.—*WPA*

**Britain's Water Supply Problem.** W. G. BALCHIN. Water & Water Eng., **61**:289 ('57). Statistics show that there is a steadily increasing consumption of water per day in Great Britain. Author discusses factors contributing to rise in consumption. He gives tables showing relation between aboveground water storage capacity and population.—*WPA*

**Water Supplies in Essex (Gr. Br.).** F. A. IRVING. J. British Wtr. Wks. Assn., **39**:116 ('57). A brief acct. is given of work of Essex County Council in field of water supply and pollution control. A survey of the water supplies points to need for planning to meet future demands, and methods for making best use of county's resources are suggested. Chem. composition of water has been studied in relation to public health.—*WPA*

**Removal of Salt From Our Canals (Neth.).** A. J. RUTGERS. Ingenieur, 's Grav. (Dutch), **69**:79 ('57). Along bottom

(*Continued on page 84 P&R*)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WINDHAM • J • ON • ELYRIA •
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(*Continued from page 82 P&R*)

of the Nordseekanaal there is a tongue of brine which cannot be removed by sluicing. It is proposed to mix brine with upper layers of water by blowing compressed air through it. Costs of the mixing are calcd.—*WPA*

## HYDROLOGY, CONSERVATION, AND IRRIGATION

**Municipal, Industrial and Irrigational Use of Available Water Supplies.** R. G. LYNCH. Ind. Wastes, 3:65 ('58). Figures are given to show great demand on water supplies in Wis., especially for irrigation; and maintenance of streamflow by restricting use of water is discussed in relation to the pending legislation and using Embarrass R. as an example. Comparisons are made with laws imposed in other states. It is considered that no permanent water rights, as proposed in pending legislation, should be established in Wis. until flow of small streams handy for farm irrigation pumps has been examd.—*WPA*

**Statistical Theory of Floods and Droughts.** E. J. GUMBEL. J. Inst. Water Engrs., 12: 157 ('58). A knowledge of magnitude of floods to be expected is important in relation to the construction of dams, bridges, and hydroelectric plants, and a knowledge of extent and frequency of droughts is required when designing water storage and irrigation facilities. Use of statistical analysis in forecasting this information is discussed with particular reference to plotting of known data on probability paper and to theory of extreme values. Examples are given relating to floods of Guarapiranga, Juquia-Franca, and Sorocaba-Ituparanga rivers, Brazil, and Colorado R. at Black Canyon, Ariz.; to droughts of river Elbe at Hamburg, Germany; and to floods and droughts of the Kaituna R. at L. Roititi, New Zealand. A bibliography of 37 references is appended. —*WPA*

**Vegetation and Water Conservation.** J. D. OVINGTON. J. British Water Wks. Assn., 40:175 ('58). Water supply and demand in United Kingdom are discussed and problem of providing sufficient water for a modern city is illustrated by reference to Liverpool. Need for more efficient collection and use of water in order to prevent water shortages is emphasized with special reference to possibility of changing type of vegetation on catchment areas, and effect of vegetation on water yield, flood control, soil erosion, and water quality. Effects of vegetation on precipitation and on movement of moisture through hydrologic cycle are also considered, including interception of precipitation by plants before it reaches soil, effects of cultivation and vegetation on pore space of soil and hence on its water absorption capacity, effect of vegetation on evaporation of water from soil, and transpiration of vegetation. Main loss of water from a catchment area is by evapotranspiration; rate of evapotranspiration by different types of vegetation is discussed. Effect of different types of vegetation on water yield has been investigated using lysimeters and water catchments. Expts. using lysimeters at Coshocton, Ohio, at Castricum, Holland, and at the Hodder catchment of the Fylde Water Board in the Yorkshire Pennines are described; and expts. with watch catchments (much larger than lysimeters) are mentioned with particular reference to studies at Coweeta, N.C. It is pointed out that results obtained in one country may not be applicable elsewhere owing to different environmental conditions. —*WPA*

**Needed: An Extra 250 bil gal of Water a Day by 1975.** Chem. Eng. News, 36:12:50 ('58). Growing demand for water, particularly for industrial purposes, may lead to a water shortage in future. Measures being studied to prevent this are discussed, including expts. on methods for demineralization of brackish and sea water, and methods for the conservation of fresh water supplies, such as the construction of dams to conserve runoff, chem. control of evapn., and reuse of water by industry.—*WPA*

**Principles of a Sound National Water Policy—A Restatement.** Civ. Eng., 27:330 ('57). In 1955, Engineers Joint Council appointed a Board of Review, to formulate a restatement of water resources policy first prepared by them in 1951. Objectives of a water policy and some basic concepts are discussed. It is concluded that plans for

(*Continued on page 88 P&R*)

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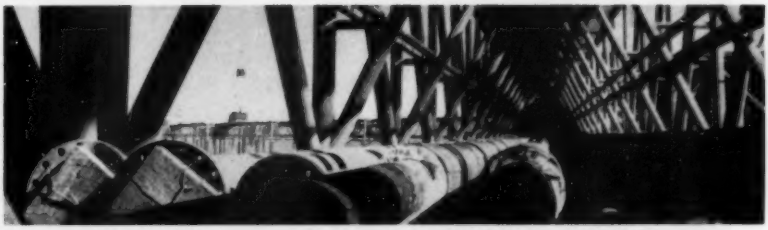

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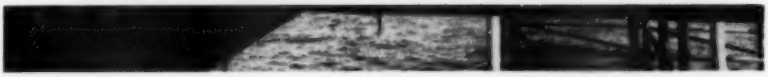

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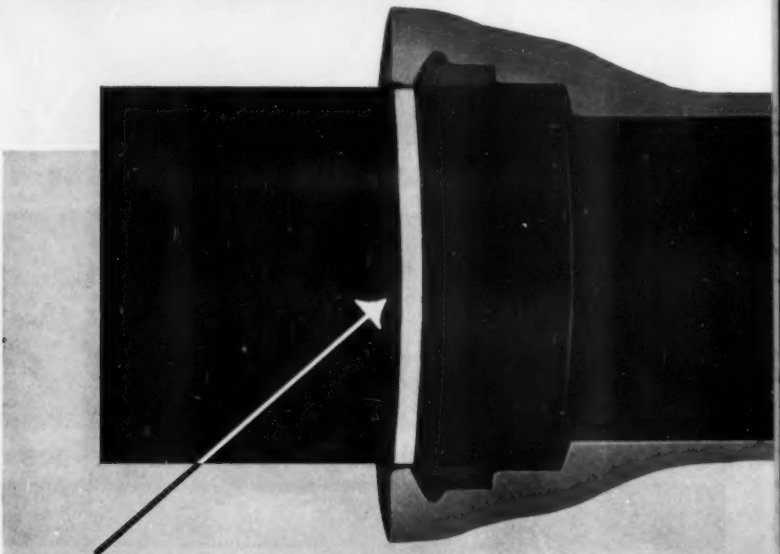

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The edge of the stripe farthest from the plain end measures approximately one-half inch less than the depth of the Bell-Tite bell. Thus, in assembly, the joint is made pressure tight when the stripe is no longer visible.

The seal is achieved by the use of a single thick-section, high durometer molded rubber gasket. When compressed in position by the entering plain end of pipe, it forms a pressure-tight seal with generous sealing area which permits ample deflection to meet casual curves or grades.

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Assembly is quick, simple and easy. Pressure-tight joint is formed instantly by merely inserting the rubber gasket and pushing the pipe home to its seat. It can be installed in a wet trench and even under water. Rate of installation usually is limited only by speed of excavation. It permits ample deflection for casual curves or grades. Bell-Tite Joint pipe is Underwriters' Listed for working pressures up to 350 psi. Available in diameters up to 24".

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(Continued from page 84 P&R)

development and use of water resources should provide for max. utilization of these resources. All projects within a river basin should, where practicable, be coordinated within framework of a comprehensive plan to assure max. effectiveness in a development of basin. There should be a board of review for the impartial analysis of all federal water resources projects, and all federal agencies engaged in development of water resources should conform to same general policies.—*WPA*

**Water Yields as Influenced by Watershed Management.** R. H. BURGY. Proc. ASCE, **84**, IR 2, Paper No. 1590 ('58). Hydrologic studies on small brush-covered watersheds in Coast Range and Sierra Nevada in California have shown that appreciable increases in runoff can be obtained by replacing brush with grass. Increases in water yield of as much as 10 in. have been measured under favorable conditions without serious acceleration of soil erosion.—*WPA*

**The Effect of Afforestation on Rainfall and Runoff.** A. J. RUTTER. Surveyor, (Lond.), **117**:189 ('58). In a paper presented at a meeting of the Institution of Public Health Engineers in London in Feb. '58, author discussed effect of afforestation on rainfall and runoff. Although, in general, forests have a negligible effect on actual quantity of rainfall, they do exert considerable influence on water yield. Effects of forests on evapn. and on subsequent disposal of water are discussed.—*WPA*

**Artificial Replenishment of Ground Water and Certain Problems of Hydrology and Geology.** W. C. LOWDERMILK. Tech. de l'Eau, **11**:123–25 ('57). Natural recharge of ground water and need for artificial recharge in arid and semiarid regions are considered. Examples of methods adopted for artificial recharge are given, with reference to the construction of "tapoons" or underground dams in Arizona, and of T-shaped dams in Southern Rhodesia, to use of cones of de-

(Continued on page 90 P&R)

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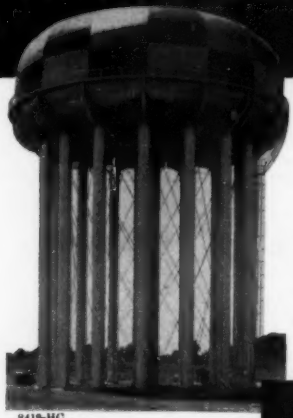

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(Continued from page 88 P&R)

tritus at San Gabriel, S. Calif., and to utilization of natural basin at San Dimas, S. Calif.—*WPA*

**Investigations of Conditions of Flow in the Ruhr District.** O. LANGE. Deutsch. Gewaesserkund. Mitt., 1:65 ('57). Author gives account of investigations into flow, water level, and rainfall in Ruhr area from '38 to '53. Gaps were caused during war years; methods used for estn. where measurements are lacking are described. Area is dealt with in 4 sections—upper Ruhr from its source to mouth of Moehne, central Ruhr from mouth of Moehne to mouth of Volme including Volme, Lenne from its source to its junction with Ruhr, and lower Ruhr from mouth of Volme to Rhine. Period is dealt with in groups of 4 yr. Conditions of rainfall and geology and hydrology of area in relation to flow, relation between rainfall and runoff, seasonal distribution of rainfall, and losses by ground subsidence are discussed. A chart of drainage area showing rainfall areas, rain gages, flow gages, and geological formation, and tables of results are given as loose-leaf appendices. Necessity for a continuation of investigation, especially in view of increasing demand for water from Ruhr and of effect on flow of impounding reservoirs, is emphasized.—*WPA*

**Rational Utilization of Water Resources in Given Region.** BRUNOTTE. Tech. Sanit. Munic., 52:159 ('57). Author discusses importance of water to life and rational distribution of available water for various purposes. A description of general water cycle is given and domestic, agricultural, industrial and hydroelectric requirements are outlined. Chem., bact., and hydrogeologic studies on water resources have been carried out and conferences between different services using water have helped toward rational distribution. Measures taken to prevent wasting of water resources, both during collection and utilization, are described, including relevant legislation in Fr. and Gr. Br.—*WPA*

(Continued on page 92 P&R)

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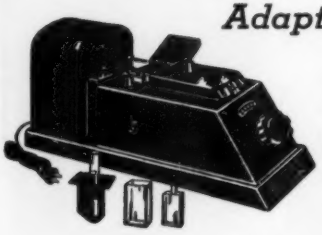

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(*Continued from page 90 P&R*)

**Hydrology and Water Development in Cyprus.** I. L. WARD; D. P. MCGREGOR; & M. GREHAN. Proc. Inst. Civil Engrs., 9:223 ('58). Climate, geol., and basic water resources of island of Cyprus are described. Hydrologic cycle occurring on island is considered, and changes in natural cycle imposed by agricultural and eng. activities are discussed. Methods of collecting and distributing surface and ground water are described, and techniques being evolved for control and conservation of ground water, including artificial recharge of selected aquifers, are reviewed. Loss of water by evapn., by transpiration from unproductive vegetation, by inefficient irrigation practices, and by surface and underground flow to sea, is considered, and future developments planned to minimize this wastage are outlined. Quant. estimates of island's gross water resources, quantity used at present, and probable limiting availability from all sources for irrigation, industrial, and domestic purposes, are given.—*WPA*

**Use of Cetyl Alcohol to Reduce Reservoir Evaporation.** F. GRUNDY. J. Inst. Water Engrs., 11:429 ('57). Author reviews briefly developments in use of cetyl alcohol for controlling evapn. from water reservoirs, and describes expts. being carried out by East African Meteorol. Dept. Methods of applying cetyl alcohol were investigated, and it was found that its use in pellet form or as a powder was not satisfactory, but it was possible to apply cetyl alcohol as a soln. in paraffin contg. a dispersing agent. Success of this method depends on wind, even a light breeze, to carry drops of liquid over surface of the water. Use of a soln. also makes it possible to detect presence of a film on a water surface. Exptl. procedure adopted was to observe pan evapn. and fall in water level in reservoir for several days before cetyl alcohol was applied. Water surface was then treated for an equal period, making similar observations. Tot. period of expt. should be such that water level does

(*Continued on page 94 P&R*)

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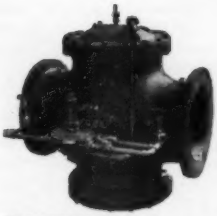
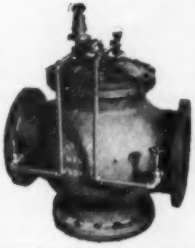


ALTITUDE VALVE

Controls elevation of water in tanks, basins and reservoirs

1. Single Acting
2. Double Acting

Maintains safe operating pressures for conduits, distribution and pump discharge



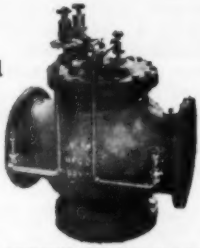
SURGE-RELIEF VALVE

REDUCING VALVE

Maintains desired discharge pressure regardless of change in rate of flow

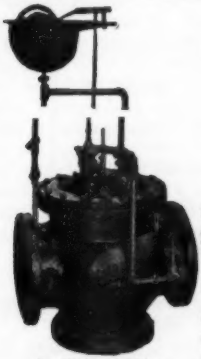
Regulates pressure in gravity and pump systems; between reservoirs and zones of different pressures, etc.

A self contained unit with three or more automatic controls



COMBINATION VALVE

Combination automatic control both directions through the valve.



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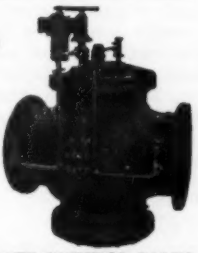

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(*Continued from page 92 P&R*)

not fall more than about 1 ft, as accuracy of results depends on assumption that seepage losses are constant during period. If it is suspected that these losses have not been constant, then dosing period should be followed by a second period without application of chemical, and results corrected if necessary. Equations for calculating the reduction in evapn. from exptl. results, are given. Author discusses desirable conditions to be looked for in selecting a reservoir for exptl. purposes, and considers effect of weather. Recent experiments in East Africa have been hindered by rainfall during normal dry season, but in 2 cases it was possible to obtain reliable results, showing reductions in evapn. of 20 and 30 per cent respectively. It is concluded that method can be applied successfully to reservoirs up to about 100 acres in area, but further studies are necessary on factors such as wave action before it can be applied to larger reservoirs.—*WPA*

**Safeguarding of Public Supplies.** W. M. MOFFETT. Pub. Health (Johannesburg), **21**: 2:9 ('58). Protection of water supplies is discussed, with special reference to practice and requirements in S. Africa, where it is necessary to safeguard quantity of supply as well as purity. Reduction of soil erosion helps to prevent loss of water storage capacity which results from deposition of silt at storage works. Water treatment plant at Port Elizabeth is described briefly as an example of methods commonly used in country; water is treated with sodium aluminate and aluminium sulfate, passed through sedimentation tanks followed by rapid gravity filters, treated with lime, and disinfected with chloramines. Advice is given concerning the chemical and bact. examn. of water supplies, including a detailed description of simple presumptive coliform organism count. —*WPA*

**Water and Agriculture.** T. SONNEMANN. Mitt. Ver. Deutsch. Gewaesserschutz, **9/10**:5 ('57). Author discusses probs. of supply of water and protection against excess water, dealing with amts. available from rainfall and agricultural, domestic, and industrial demands, methods of protection against flooding from sea and rivers, increased use of water for improving agricultural yields and reclaiming waste land, use of impounding reservoirs and regulation of streamflows for preventing waste and equalizing flow, artificial methods of increasing ground water supply, importance of protection of streams from poln., and need for a comprehensive water law.—*WPA*

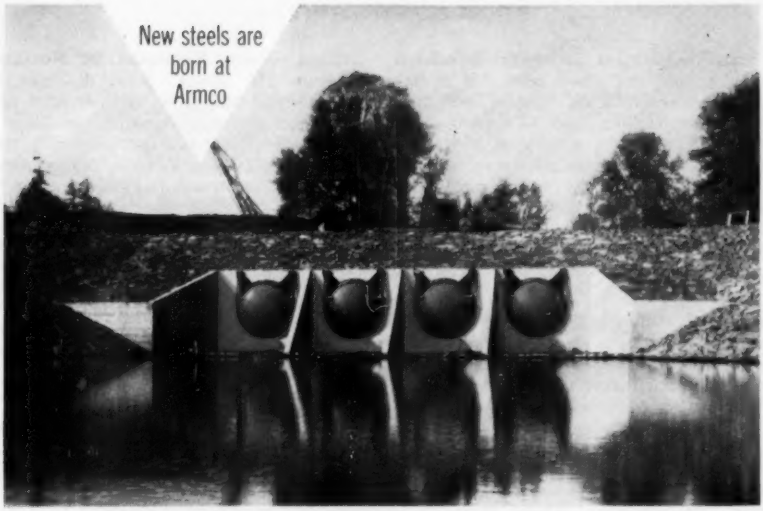
**Availability of Water Resources (Gr. Br.).** J. Brit. Waterworks Assn., **39**:430 ('57). In panel discussion at 46th annual conference of British Waterworks Assn. various speakers considered water resources of Gr. Br. and future demand for domestic, industrial, and agricultural use. It was suggested that reuse of water by industry should be encouraged, that artificial recharge of ground water should be further investigated, and that rivers might be used to transfer water from areas of heavy rainfall to drier parts of country.—*WPA*

**The Construction and Operation of Large-Scale Irrigation Organizations in Hungary.** W. SPERLING. Wasserwirtschaft (Stuttgart), **47**:252 ('57). A detailed description is given of organization of large-scale irrigation in Hungary, dealing with design of irrigation system, amt. and distribution of water, crops, and planning of irrigation throughout year.—*WPA*

**Water Conservation—A World Problem.** E. RIDEAL. Surveyor (London), **117**:1119 ('58). In a paper presented at Public Works and Municipal Services Congress in '58, problem of conservation of water for domestic, agricultural, and industrial use, and for hydroelectric power, is discussed. Special attention is paid to conservation of water by geol. surveys; by reduction of evapn.; by reuse of trade waste waters in industry; and by demineralization of brackish water and sea water, using evapn. and distillation, freezing, ion exchange, osmosis, and electrodialysis.—*WPA*

**Use of Ground Water and Its Effects on Hydrological Equilibrium.** R. D. DHIR. Tech. de l'Eau, **12**:34:39 ('58). Role of ground water in hydrologic equilibrium and effects of extraction of ground water are discussed, with special reference to effects

(*Continued on page 96 P&R*)

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Armco also produces a complete line of sluice gates, roller and radial gates, and all accessories required for complete gate installations. For details on Armco Gates write to Armco Drainage & Metal Products, Inc., 6489 Curtis Street, Middletown, Ohio.

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| **SIZES** | |
| round opening | 4″ to 120″ diameter |
| square and rectangular | 24″ x 24″ to 96″ x 96″ |
| **SEATING HEADS** | from 10′ to 50′ |
| **CONSTRUCTION** | cast iron, cast steel, fabricated steel |
| **SEATING FACES** | bronze, cast iron, cast steel |

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(*Continued from page 94 P&R*)

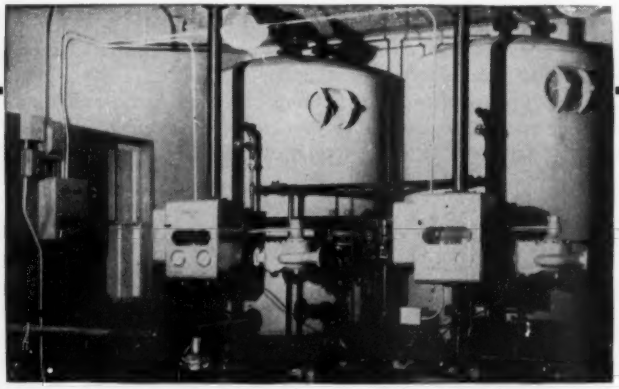
on evapotranspiration, infiltration, associated surface waters, and water table. It is emphasized that inventory method, normally used to determine the quant. of ground water which it is permissible to extract, and based on assessment of quants. of water entering and leaving aquifer by various procedures, does not consider possible effects of such withdrawal of ground water on other aspects of the hydrologic cycle, such as evapotranspiration and infiltration.—*WPA*

**Proposed Changes in Eastern Water Use Policies.** M. STEIN. Proc. ASCE, **84**:SA5, Paper No. 1777 ('58). In eastern states, which use riparian doctrine of water use, more definite water resources policies are being evolved, objectives being equitable apportionment of water among the many conflicting demands, the improvement of water quality, and the stabilization of water flows and water supply. At present a "Model Water Use Act" is being drafted for consideration by states.—*WPA*

**Ground Water Resources in Northeast Belgium.** H. RONSE. Tech. de l'Eau, **12**: 133 ('58). Author gives a summary of principal water-bearing resources available in northeast region of Belgium, classifying them under headings of cretaceous, landenien, tertiary sand and quaternary deposits.—*WPA*

**Hydrology and Water Development Schemes in Bulgaria.** I. MARINOV. Water & Water Eng., **62**:477 ('58). With a view to detg. water resources of Bulgaria, network of gauging stations has been set up on a no. of rivers, to measure runoff, turbidity, and chemical compn.—*WPA*

**Soil and Water Problems in Chad District (AFr.).** H. FRANZ. Oesterr. Wasserwirtsch., **10**:48 ('58). Author deals with problems of water supply and agriculture in Chad district of Fr. Equatorial Africa where there is flooding during rains and drought is serious in dry season.—*WPA*



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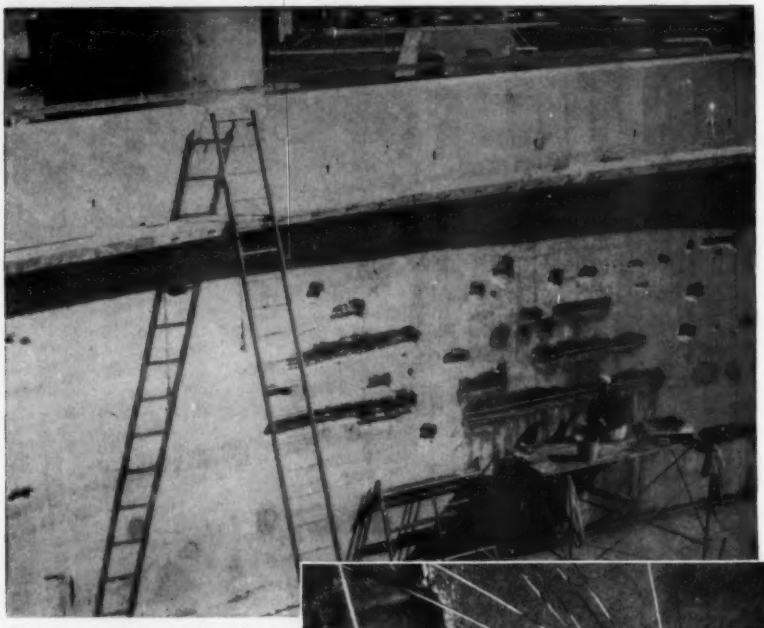
# CONCRETE NEEDS CORROSION



Damage caused by sub-surface corrosion of steel reinforcing rods is shown in this view of tank interior.

Close-up of pre-stressed tank exterior shows large sections of gunite which were forced from wall by corroding wires.

# PROTECTION, TOO

## Case history of sub-surface corrosion shows porosity of concrete

When the Koppers Contract Coating Department was called in by an East Coast chemical processing firm for its recommendations on waterproofing sea-water treatment tanks, it found the conditions shown on the facing page.

Some tanks, up to 200′ in diameter, were formed of 16″-thick reinforced concrete. Although various coating systems had been tried in attempts to stop water migration, the concrete was spalled away in many areas by sub-surface corrosion of reinforcing steel.

Other tanks of the pre-stressed type at this same location were also attacked by corrosion in less than two years. Pre-stressed wires around the tank had failed due to corrosion caused by water migration through the walls and from the outside, through as much as a 1″ protective layer of gunite.

After repairs to the concrete, the walls of the tanks are being coated with Bitumastic protective coatings by the Koppers Contract Coating Department. The proven waterproofing ability of coal tar, principal ingredient of Bitumastic coatings, protects concrete against the penetration of water and subsequent corrosion attack on imbedded steel. And the thick film characteristics of Bitumastic coatings make them long-lasting, too. For the tough jobs, it pays to specify the unequalled corrosion protection of Bitumastic protective coatings.

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**COATINGS AND ENAMELS**

(Continued from page 60 P&R)

**AEC** has established an Office of Health & Safety, which has been assigned the principal responsibility for developing and recommending health standards to protect workers and the public from radiation induced by atomic energy. The new office will also cooperate with state officials in the field of radiation protection. Dr. Forrest Western has been named acting director.

**Sidney B. Bowne,** partner in the engineering firm of Sidney B. Bowne & Son, Mineola, N.Y., died Sep. 16, 1959. He was 71. Also a member of Litchfield, Whiting, Bowne & Assocs., architects and engineers, New York, he founded the Mineola firm in 1922. Mr. Bowne supervised a number of water districts organized by communities in Nassau and Suffolk counties on Long Island, N.Y. He joined AWWA in 1924.

**John G. Flanigan,** member of the North Jersey District Water Supply Commission, died Aug. 20, 1959, in New York City, following an operation. He was 68. Born in Long Branch, N.J., he received his law degree from Fordham University and was a practicing lawyer since 1917. He had served on the water supply commission since 1945 and had been an AWWA member since 1952.

**Horace B. Horton,** board chairman of Chicago Bridge & Iron Co., died Sep. 17, 1959, in Chicago. He was 73. Born in 1885, he held a B.S. degree from the University of Chicago and

(Continued on page 102 P&R)

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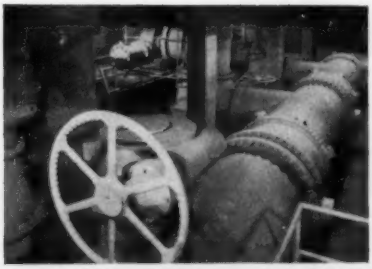
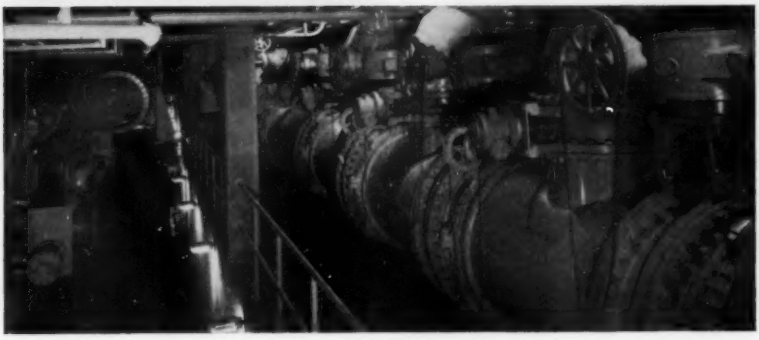


Shown in the Pumping Station are three 20-inch ROTOVALVE pump check units, four 54-inch suction header butterfly valves, and three 24-inch pump suction butterfly valves.

South Holly Filter Plant interior shows 9 Allis-Chalmers transfer pump station butterfly valves at the right, a wash water controller butterfly valve at left center, and 3 wash water butterfly valves at the lower left.

*Consulting Engineers:*
*Freese, Nichols & Endress*



## South Holly Station In Fort Worth Installs
## 71 ALLIS-CHALMERS VALVES

At the city of Fort Worth's new, 50 MGD South Holly Filter Plant and High-Service Pumping Station, 66 Allis-Chalmers rubber-seated butterfly valves, in 18-inch to 54-inch sizes, have been installed. Five 16- to 20-inch A-C ROTOVALVE units are also being used on pump check service.

A-C rubber-seated butterfly valves are known for their dependable operation with few maintenance problems. Through-type rubber seats give complete body protection. Wedging action of the vane against the tough, flexible rubber assures positive closure, even around the shaft bosses. Angle-seated vanes can be adjusted to give tight shutoff throughout the valve's life by resetting the operator stops.

To obtain complete information about the full A-C line of butterfly, ROTOVALVE and ball valve units, contact your A-C Valve Representative, or write Allis-Chalmers, Hydraulic Division, York, Penna.

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1110

(Continued from page 100 P&R)

took graduate work in engineering at the University of Illinois. In 1907 he joined Chicago Bridge & Iron, which his father had founded. He was named president in 1945 and chairman of the board in 1956. Mr. Horton served as a member of the National War Labor Board during World War II and was on the Hoover Commission in 1954–55. He had represented his company in AWWA since 1946.

**C. Kelsey Mathews,** a partner of Burns & McDonnell Engineering Co., died Aug. 19, 1959, in Kansas City, Mo., at the age of 62. Born in Lexington, Mo., in 1896, he received a B.S. in civil engineering from the University of Kansas in 1919. Except for three years of study at the University of Illinois, he had been with Burns & McDonnell since 1919. During World War II he was chief engineer on the design and construction of Camp Crowder, Mo. He became a partner of the firm in 1947.

A member of AWWA since 1944, he was also a life member of ASCE. He was also a member of the American Institute of Consulting Engineers and the National Society of Professional Engineers.

**Conrad W. O'Connell,** who recently became affiliated with the Plainfield-Union Water Co., died Sep. 11, 1959, at his home in Westfield, N.J. He was 53. Born in Newark, N.J., he had returned to the state in 1958 from California, where he had been general manager and vice-president of Questad Builders, Inc., of South Pasadena.

A member of AWWA since 1956, he was also a member of ASCE.

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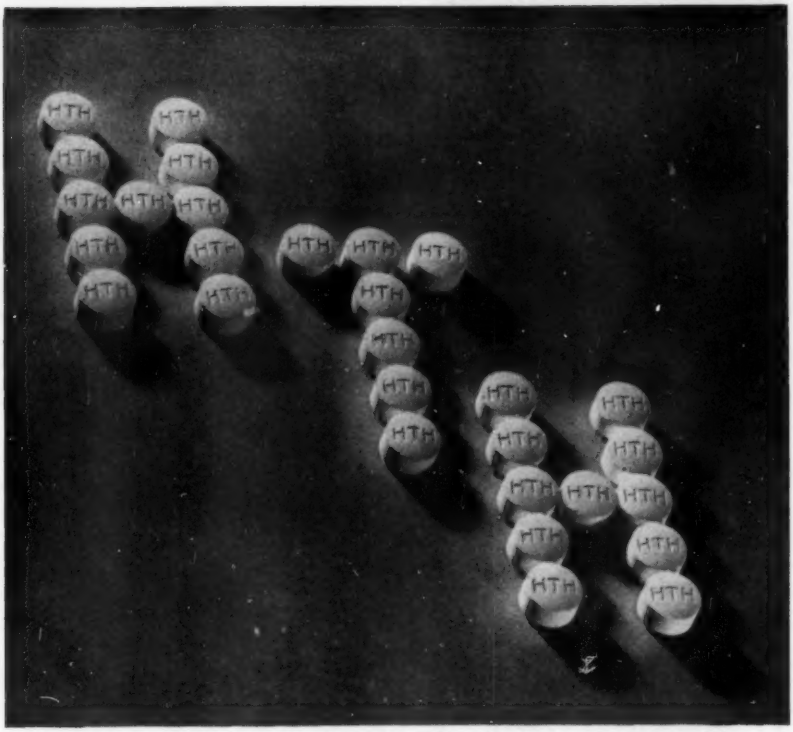


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**Gravimetric feeders** for handling dry materials at high rates are discussed, with photographs and drawings, in a new 4-page publication. Bulletin 35.20-2 may be obtained from B-I-F Industries, Inc., 345 Harris Ave., Providence 1, R.I.

**Concrete,** as it is used in water and sewage installations, is the subject of a 20-page booklet, based on photographs and studies of 35 treatment plants. A copy of Bulletin MBR-P5 is available from The Master Builders Co., Cleveland 3, Ohio.

**Voltmeters** specially designed for corrosion control and cathodic protection are illustrated and described in a 2-page bulletin, No. 1-3. A copy may be obtained from Associated Research, Inc., 3758 Belmont Ave., Chicago 18, Ill.

**Valves** that are used for regulation and control of water under conditions of free discharge are discussed, with photographs and diagrams, in a 4-page leaflet. Bulletin 02B9154 is available by writing Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.

# at the Massena, N. Y., intake of the St. Lawrence Project

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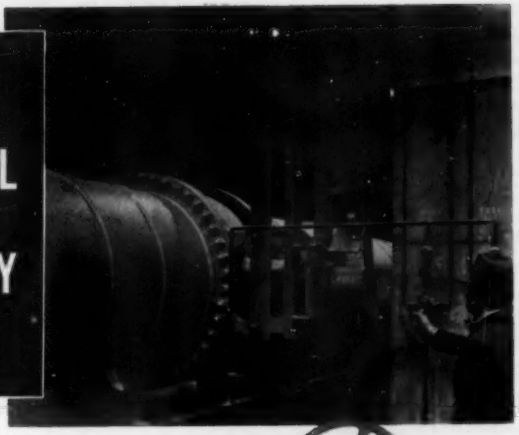

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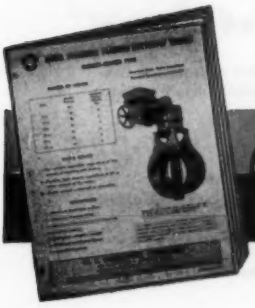

There are many such successful Rockwell valve installations for water applications. Bulletin 581 tells why.

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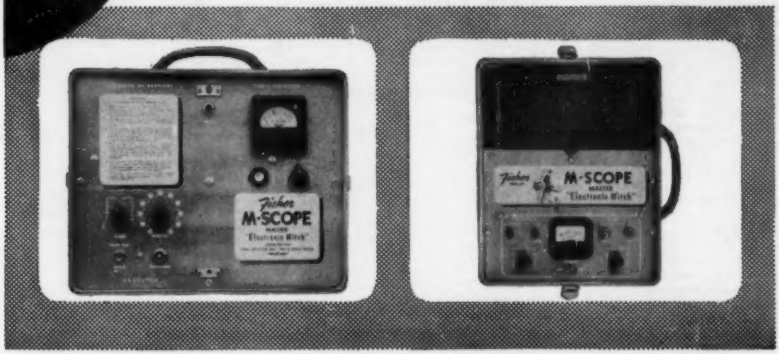


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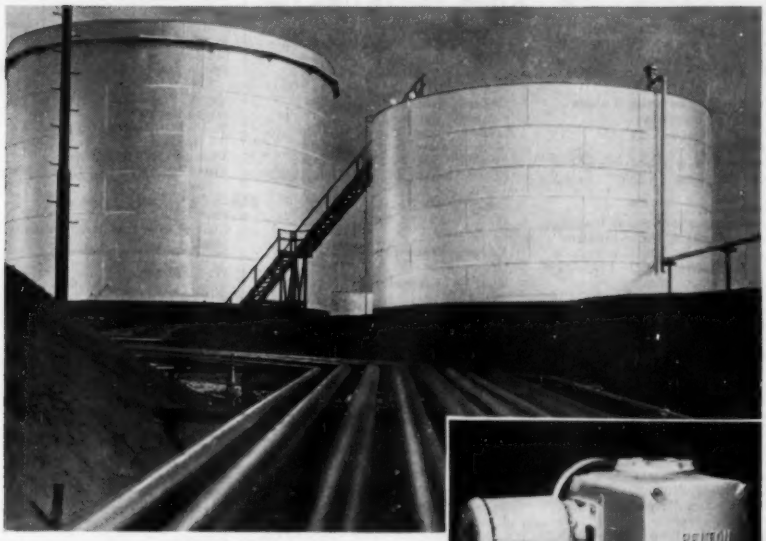
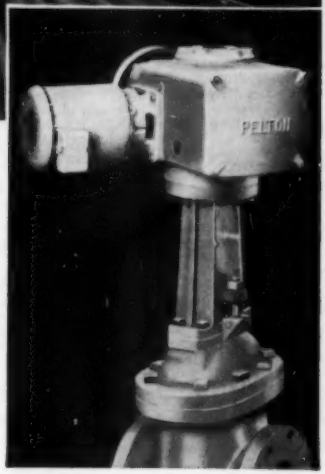
# Why it will pay you to insist on Pelton Valve Operators






Clear-cut reasons for the wide acceptance of Pelton Valve Operators are not hard to find. The remote control operation feature produces significant time and labor savings, while the manual control can be utilized in emergency operation. By means of self-locking worm gear sets and a planetary gear system, both the remotely controlled motor drive and the local handwheel are directly connected at all times to the output load. This permits the handwheel to be continually engaged, yet prevents rotation during periods of electrical operation.

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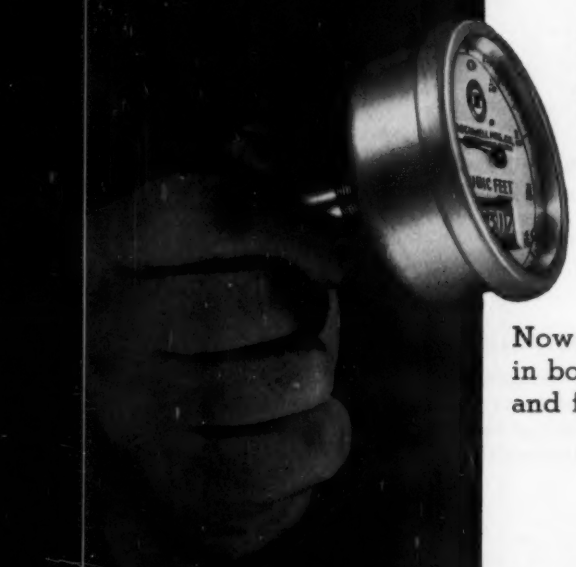

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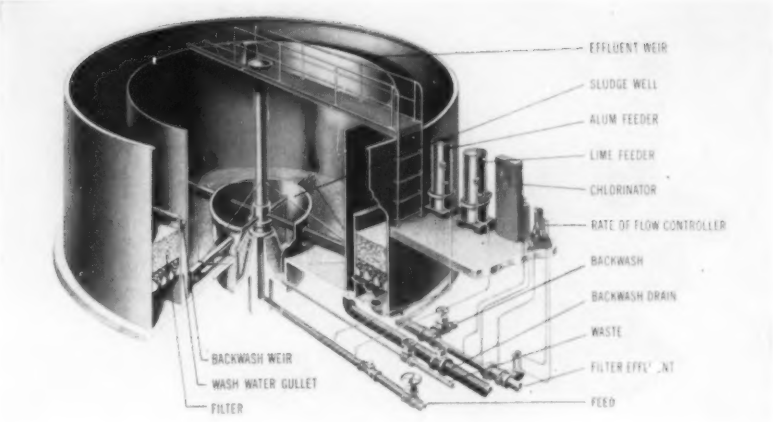


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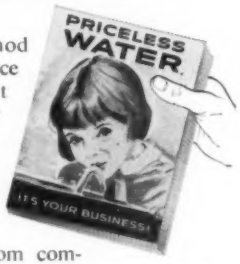


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